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ABUNDANCES OF Na, Sc, Cr, Mn, Fe, Co, AND Cu In 18 METEORITES AND 146 INDIVIDUAL CHONDRULES

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INTRODUCTION

This progress report in the third year of research on elemental abundances in meteoritic and terrestrial matter covers the contract period from December 1, 1963, through February 29, 1964.

During this quarter, abundances of seven elements--Na, Sc, Cr, Mn, Fe, Co, and Cu--were determined by the technique of instrumental neutron activation analysis (INAA) in 18 meteorites and 146 individual chondrules, separated from seven meteorites. The meteoritic specimens were obtained from C. B. Moore of the Nininger Meteorite Collection and Arizona State University, B. H. Mason of the American Museum of Natural History, E. P. Henderson of the Smithsonian Institution, and H. C. Urey of the University of California at San Diego.

During the quarter, a paper entitled "Cadmium Abundances in Meteoritic and Terrestrial Matter," by R. A. Schmitt, R. H. Smith, and D. A. Olehy, was published in Geochimica et Cosmochimica Acta, Vol. 27, pp. 1077-1088, 1963. Another paper entitled "Rare-Earth, Yttrium, and Scandium Abundances in Meteoritic and Terrestrial Matter - II," by R. A. Schmitt, R. H. Smith, and D. A. Olehy, was also published in Geochimica et Cosmochimica Acta, Vol. 28, pp. 67-86, 1964. A talk was given at the recent meeting in Cleveland, December 26-30, 1963, of the American Association for the Advancement of Science, on "Abundances of Na, Sc, Cr, Mn, Fe, Co, and Cu in Chondritic Meteorites and in Individual Chondrules," by G. G. Goles, R. A. Schmitt, and R. H. Smith.

RESULTS AND DISCUSSION FOR ABUNDANCES OF Na, Sc, Cr, Mn, Fe, Co, AND Cu IN 18 METEORITES

The INAA procedure for determination of these seven elements has been described in detail in the previous report.[1]

Abundances were determined in four carbonaceous chondrites, Murray, Santa Cruz, Lancé, and Mokoia; one enstatitic chondrite, Abee; one L-group chondrite, Walters; three pallasites, Brenham, Molong, and Four Corners; two amphoterites, Näs and Jelica; four eucritic (Ca-rich) achondrites, Haraiya, Nobleborough, Pasamonte, and Sioux County; and in three Ca-poor achondrites, Cumberland Falls, Pesayanoe, and Novo Urei.

Table 1* lists the abundances for nine meteorites, while in Tables 2, 3 and 4 the abundances of the remaining nine meteorites have been included in the respective meteoritic categories. Abundances of Table 1 have been included in the average abundances of Table 5, which is the revised Table 2 of Ref. 1.

In addition to the definite fractionation of Na, Mn, and Co within the three types of carbonaceous and ordinary chondritic meteorites, Cu also appears to exhibit fractionation with respect to Si from 490 ±10 (Type I), 400 ±10 (Type II), 350 ±30 (Type III), 260 ±50 (ordinary chondrites), and 370 ±60 Cu atoms/10^6 Si atoms (enstatitic chondrites).

The abundance of Na in another specimen of Murray was much lower by a factor of ~3 compared with three other Type II carbonaceous chondrites. Since abundances of the other six elements, Sc to Cu, agree with those of the three other Type II carbonaceous chondrites, many different Murray stones will be checked for the uniqueness of the low Na content.

ABUNDANCES IN AMPHOTERIC CHONDRITES

Abundances of these seven trace elements in amphoteric or LL-group chondrites have been compiled in Table 2. Of these, four are observed falls and one, Näs, is a find; however, no abundance differences were found for Näs compared with the others. These meteorites have been recently

*All tables appear at the end of this report, immediately preceding all the figures.

commented on by Mason and Wiik,[2] who analyzed the prototype Manbhoom and surveyed the composition of the remainder. The amphoteric abundances of these seven elements have been compared with abundances of other meteoritic categories in Table 5. The average abundances of Fe in Table 2 represent the grand average of this work and that of others.

In Table 2, Na abundances in amphoterites are fairly uniform with a ±6% mean deviation. As commented on previously,[1] the past Na values of Edwards and Urey[3] are trustworthy. Mean deviations of abundances in five amphoterites are Sc 5%, Cr 14%, Mn 9%, Fe 7%, Co 17%, and Cu 5%, all of which are in line with the small mean deviations[1] of the L-group chondrites. These data support the conclusions of Kvasha[4] and Mason[5] that the brecciated amphoteric chondrites should be categorized as a subclass of the hypersthenic chondrites, with the chief differences between hypersthenic and amphoteric chondrites being that amphoteric chondrites have more olivine and less pyroxene, and have considerably more recrystallization and brecciation.

Six additional amphoteric chondrites, obtained recently from Mason, will be subjected to INAA; any chondrules (where present) will also be analyzed individually.

ABUNDANCES IN Ca-RICH ACHONDRITES

Four Ca-rich eucritic achondrites, analyzed during the past quarter, have been included in Table 3, a composite abundance table for these achondrites that represent ~5% (an appreciable amount) of observed meteoritic falls. In general, no significant differences exist between abundances of Na, Sc, Cr, Mn, Fe, and Cu for the eucritic- and howarditic-classed achondrites. It now seems fairly certain that this class of achondrites has been passed through nearly identical physicochemical history.

Although only three howardites were analyzed, two of them have higher Co contents, probably attributed to the presence of some trace quantities of metallic iron. Assuming (a) that the Ca-rich achondrites are derived from fractionation of L-group chondritic matter (see below) and (b) that 540 ±120 ppm Co and 6.5% metallic Fe-Ni are present[6] in the metallic phase of L-group chondrites, the estimated Co abundance of Petersburg calculates at $(0.5/6.5)\ 540 = 42 \pm 10$ ppm, which is in agreement with the observed 54 ±5 ppm Co. Fredriksson and Keil[7] detected metallic iron in the Kapoeta achondrite; a concentration of ~0.25% metallic Fe-Ni is predicated for Kapoeta, assuming a derivation as given above. By the same assumptions, ~0.02% metallic Fe-Ni is present in the other Ca-rich achondrites that average 3 ±2 ppm Co.

Abundances of these seven elements have been compared with the

averages in 29 L-group chondrites mainly on correlation of the total Fe and Co contents. With 25.9 ±2.1% and 21.1 ±2.4% total iron[1] and 16.8% and 6.5% metallic Fe-Ni[6] in H-group and L-group chondrites, respectively, 9.1% and 14.6% Fe are present as nonmetallic or oxidized iron in the H- and L-chondrites. The latter value of 14.6% agrees well with the observed 15.2 ±1.3% in the Ca-rich achondrites. Of course, it is implicitly assumed that in the fractionation of L-group chondritic matter to give Ca-rich achondrites as one of the fractionation products, the metallic phase segregated, apparently leaving ~0.02% metallic Fe-Ni (corresponding to 3 ppm Co) present in the average Ca-rich achondrite. In conclusion, a comparison of the abundances of total Fe, metallic Fe-Ni, and Co strongly suggests that the Ca-rich, eucritic and howarditic achondrites are genetically related to the L-group or hypersthenic chondrites. Moore[8] and Mason[9] have suggested from mineralogical and petrological studies that Ca-rich achondrites may be derived from fractionation of chondritic matter.

In the Ca-rich achondrites, Cu has been depleted by a factor of ~13, Sc enriched by ~3, and Na depleted by ~2, compared with L-group chondrites. Since Mn is depleted by ~0.5 and Cr and Sc are severely depleted by factors of ~20 and ~10, respectively, in pallasitic olivines, their abundances should be enhanced in these Ca-rich achondrites--if they reside in the pyroxene phase--assuming pallasites to be auxiliary fractionation products of hypersthenic chondritic matter. The unexpected depletion of Cr in Ca-rich achondrites cannot be attributed to direct chromite removal, since only ~0.32 of all Cr in L-group chondritic matter[1] is present as chromite. In order to understand the genetic relationships (if existent) between L-group chondrites and the Ca-rich achondrites, INAA will be performed on chondritic minerals, viz., olivines, pyroxenes, troilite, etc.

At the present time, over-all elemental abundances in ordinary chondrites may be calculated[9] assuming a L/H ratio of 100/77 for the number of L-group to H-group chondrites. If the L-group chondritic matter were genetically related to the Ca-rich achondrites, the L/H ratio would have to be increased to ~150/77 or ~2. The reasoning goes as follows: The 14 rare earth elements (REE), and other trace elements such as Ba, U, Th, etc., have been enriched [10][11] by ~10 in Ca-rich achondrites compared with ordinary L- or H-group chondrites. Furthermore, no internal REE fractionation (i.e., the REE among themselves) has occurred in both the L- and H-chondrites and in the Ca-rich achondrites. Assuming that the observed fall ratio is proportional to the actual volume ratio of stone meteorites, the REE data suggest that about ten volumes of L-chondritic matter must be fractionated for each observed volume of Ca-rich achondritic matter. With ~5% (or 5 volumes) observed falls of Ca-rich achondrites, ~50 volumes of L-chondritic matter must have been magmatically processed. Only a small fraction, say ~3.1%, of observed falls are Ca-poor achondrites and pallasites. Therefore, it may be further argued that a

large percentage of the other auxiliary fractionation products, Ca-poor achondrites and pallasites--which have very low abundances of the REE--have been either irrevocably lost for earth capture or have a distinctly different proportionality ratio for observed falls to volume falls compared with the ordinary chondrites and the Ca-rich achondrites. Possibly, such huge amounts of Ca-poor achondrites, viz., Norton County, "swing" the proportionality constant.

In the above, we have carefully avoided any correlation with primary origin of any meteoritic matter but have suggested correlations within the meteoritic family.

ABUNDANCES IN Ca-POOR ACHONDRITES

Abundances of Na, Sc, Cr, Mn, Fe, Co, and Cu in Ca-poor achondrites have been compiled in Table 4. Meaningful correlations must await the analyses of more specimens of all subclasses of Ca-poor achondrites.

CUMULATIVE FREQUENCY DISTRIBUTIONS FOR ABUNDANCES OF Na, Sc, Cr, Mn, Co, AND Cu IN CHONDRITIC METEORITES

In Figs. 1 through 7,* cumulative frequency distributions have been plotted for the trace elemental abundance data given in Ref. 1, using linear probability paper. This method has been used to conveniently represent the statistical nature of element distribution, principally by Ahrens[12]--see his 1963 paper for pertinent literature. Very briefly, a straight line through the cumulative frequency point indicates that the distribution of a particular element is a normal or "Gaussian" distribution. An example of cumulative frequency for Fig. 1 will be given. The first (×) value designates a cumulative frequency of 15% of the H-group chondrites that have Na abundances up to and including 5500 ppm; likewise, an (×) value of 95% cumulative frequency indicates that 95% of the H-group chondrites have Na abundance up to and including 7000 ppm. The abscissa merely reflects the integrated probability function up to a given abundance.

Abundances of all the seven trace elements in Figs. 1 through 7--Na, Sc, Cr, Mn, Fe, Co, and Cu--may be represented by a "normal" distribution, in both the H- and L-group chondrites, at least within the limits of the relatively small number of analyzed specimens. Also, a steeper slope is directly correlated with a larger dispersion. All slopes are closely similar for both the H- and L-group chondrites with the single exception of Cu. Obviously, more analyses are required in order to unambiguously assign a "normal" distribution for these elements and to determine differences (if present) between dispersions for the H- and L-group chondrites.

The author subjected Keil's[6] accurate data on the concentrations of total silicates, metallic Fe-Ni, troilite, and chromite to cumulative frequency distributions given in Figs. 8, 9, 10, and 11. Each phase corresponds closely to a "normal" distribution. The "normal" distributions of the Keil's data[6] and that of this work contrast sharply with the lognormal cumulative frequency distributions obtained by Ahrens[12] for concentrations of both macro- and trace elements in igneous rocks. (A lognormal distribution is simply a distribution wherein the log of the concentrations defines a normal distribution function.) This sharp contrast merely reflects the well-established fact that igneous rocks and chondritic meteorites have had very different physicochemical histories.

*All figures appear at the end of this report.

Despite the criticisms of Miller and Goldberg,[13] Chayes,[14] and Aubrey,[15] the author concurs with Ahrens[16] that "We seek to find a distribution which fits the various sets of observations reasonably well and which may therefore be used for the geochemical purpose of comparison and prediction."

Subjecting inaccurate meteoritic abundance data (of which the meteoritic literature is rather replete) to this cumulative frequency test only reveals "normal" distributions of the error spreads of a particular experimental method and not the true distributions of the chemical abundances.

RESULTS AND DISCUSSION OF ABUNDANCES OF Na, Sc, Cr, Mn, Fe, Co, AND Cu IN 146 INDIVIDUAL CHONDRULES

Tables 6 through 12 summarize the abundances of Na, Sc, Cr, Mn, Fe, Co, and Cu determined in 146 individual chondrules obtained from seven chondrites. Some of these data were presented in Ref. 1. The chondrites are: Santa Cruz (Type II carbonaceous chondrite); Lancé and Mokoia (Type III olivine pigeonitic carbonaceous chondrites); Chainpur (Type III olivine pigeonitic noncarbonaceous chondrite); Allegan and Ochansk (H-group chondrite); and Bjurböle (L-group chondrite). Tables 13 through 19 give the abundances of these seven elements for individual chondrites.

Figures 12 through 18 graphically present histograms of the abundances and Figs. 19 through 25 give the corresponding cumulative frequency distributions.

From these abundant abundance data, the following remarks and correlations may be made. Because these data represent only a few chondrules from a few meteorites, no definitive trends have been established. The author suggests that at least a minimum of three to five meteorites (if available) from each carbonaceous or noncarbonaceous chondritic category should be studied before meaningful speculation about origin, metamorphism, etc., are offered.

1. Na IN CHONDRULES (Table 6; Figs. 12 and 19)

Na abundances (probably in plagioclase minerals) in chondrules from carbonaceous chondrites average ~32% mean deviation compared with ~15% in chondrules from ordinary chondrites. A mass effect on Na abundances may be present in Santa Cruz (Type II) and in Ochansk (H-group chondrite), and no Na dependence (as expected) in magnetic chondrules seems present. Within the three types of carbonaceous chondrules, the ratios of Na(chondrules) to Na(chondrite) vary from ~0.26 in Type II Santa Cruz to ~1.75 in Type III Lancé, compared with 1.32 ±0.11 for the three ordinary chondritic chondrules.

Although the cumulative frequency distributions are defined by about 20 total chondrules for each distribution, "normal" distributions are not inconsistent with the chondrule data of six chondrites. Na abundances in Mokoia chondrules seem to show a positive skewness. Again, none of these data suggest a "primordial" Na.

2. Sc IN CHONDRULES (Table 7; Figs. 13 and 20)

Sc (probably present in pyroxene and apatite minerals) abundances show no (as expected) magnetic chondrule effect and no chondrule mass effect. Sc abundances for Santa Cruz and Lancé are in data reduction. Ratios of Sc(chondrules) to Sc(chondrites) range from 0.94 to 1.47 with no significant differences in ratios between Type III carbonaceous chondrites and ordinary chondritic chondrules (an average 30% difference in the ratios between these two groups is calculated). The scatter or dispersion of Sc(chondrule) abundances is very similar for all five chondrites, with more than a few chondrules having Sc abundances higher than 13 ppm, the highest abundance found in 49 H- and L-group chondrites.

3. Cr IN CHONDRULES (Table 8; Figs. 14 and 21)

No significant chondrule mass or magnetic effects have been observed for abundances of Cr, which is probably present in chromite and pyroxene minerals. As with Sc, Fe, and Co, abundances of these elements in chondrules from Type II Santa Cruz and Type III Lancé are in data reduction. A difference of ~30% in ratios of abundances of Cr(chondrule) to Cr(chondrite) appears to exist between Type III chondrules and ordinary chondritic chondrules. The Cr ratio difference (if real) is exactly opposite to the Sc ratio differences (see above) between these two broad chondritic categories.

Cumulative frequency distributions of Cr in chondrules from all five chondrites apparently define "normal" Gaussian distribution functions.

4. Mn IN CHONDRULES (Table 9; Figs. 15 and 22)

Most significant of Mn abundances in chondrules is the constancy with a ~±5% mean deviation from three ordinary H- and L-chondrites. This contrasts sharply with the low (by a factor of ~3) Mn abundances of ~1000 ppm in chondrules from three carbonaceous chondrites compared with 2970 ppm in ordinary chondritic chondrules. Also, the mean deviations were large, ~30%, in the carbonaceous chondrules. Note that chondrules from Chainpur are broadly scattered (see Fig. 15). A comparison of the ratios of Mn(chondrule) to Mn(chondrite) indicates that Mn is enriched by 2 in ordinary chondritic chondrules. These low Mn abundances in Santa Cruz, Lancé, and Mokoia chondrules are more in line with solar Mn values. Urey[17] has pointed out that Mn abundances in ordinary chondrites seem to be high by a factor of ~2. More chondrules from additional carbonaceous chondrites must be analyzed to establish any trends.

The singularity of Mn abundances in Chainpur chondrules stands out

prominently in the cumulative frequency distributions of Fig. 22, with the ordinary and carbonaceous chondritic chondrules appreciably separated. However, the ordinary and the carbonaceous distributions are each narrowly grouped.

5. Fe IN CHONDRULES (Table 10; Figs. 16 and 23)

Abundances of Fe in Mokoia and Chainpur show a broad scatter, with a mean deviation of ~50% compared with ~25% in chondrules from three ordinary chondrites. If the total Fe content in the whole-rock-type chondrite Chainpur is low--Type III grouped carbonaceous chondrites have ~25% total Fe[18]--then no marked difference exists between the average ratios of Fe(chondrules) to Fe(chondrites) in the two broad groups of ordinary and carbonaceous chondrites. A higher total Fe in the chondrite Chainpur will obviously reduce the Chainpur ratio of 0.62 (last column, Table 10).

As pointed out in Ref. 1, a mass effect appears in Ochansk and Chainpur chondrules, with Fe content increasing with chondrule mass. Moreover, magnetic chondrules in Chainpur have more Fe than do the nonmagnetic chondrules.

Lower Fe abundances, as observed in chondrules, obviously correlate better with the solar Fe abundance.

The larger slopes of the cumulative frequency distributions of Mokoia and Chainpur clearly show the wide dispersions in the Type III carbonaceous chondrites. Again, all Fe abundances may be approximated by a "normal" Gaussian distribution. Mineralogical studies of the chondrules very low in total Fe (some as low as ~1%) would be most interesting.

6. Co IN CHONDRULES (Table 11; Figs. 17 and 24)

Abundances of Co in chondrules from Type III carbonaceous chondrites have large dispersions and on the average have about ten times more Co present compared with ordinary chondrules. In Ochansk chondrules, large Co abundances are associated with magnetic chondrules (Table 14) with apparently no mass effect in chondrules from ordinary chondrites.

In Chainpur chondrules, the magnetic effect is pronounced, with large Co contents in magnetic chondrules. An examination of Mokoia--all magnetic chondrules--reveals no correlation between average total Fe and Co; e.g., in Table 16, the Co abundances in chondrules 1 and 2 are essentially the same at 250 ppm while the corresponding total Fe varies at 17.4 ±3.0% and 2.3 ±2.5%, respectively. Only very high total Fe abundances

correlate with very high Co contents; e. g., chondrules 11, 18, and 23 at 21.0%, 22.3%, and 18.9% total Fe have 760 ±40, 720 ±40 and 720 ±30 ppm Co, respectively. (See Ref. 1 for experiments that have checked the abundance calculations with varying amounts of Fe, Sc, and Co.) Likewise, within the magnetic chondrule group of Chainpur, no significant correlation exists between total Fe and Co.

Experiments will be performed to determine the metallic Fe-Ni content of these chondrules. The Co contents in Santa Cruz and Lancé are now in data reduction.

Cumulative frequency distributions of Mokoia and Chainpur (Fig. 24) again reflect the wide dispersions of Co, while the Co distributions for chondrules from ordinary chondrites are closely grouped.

7. Cu IN CHONDRULES (Table 12; Figs. 18 and 25)

Cu abundances in chondrules manifest large dispersions and exhibit no apparent trends among magnetic and nonmagnetic chondrules from ordinary chondrites and in chondrules of different masses. Ratios of Cu(chondrules) to Cu(chondrites) at ~0.5 agree fairly well for seven chondrites.

Abundances of Cu appear to be weakly correlated to the Co content in Mokoia magnetic chondrules; i. e., for the majority of chondrules the Co to Cu ratio holds at ~5. Even small concentrations of Cu have negligible amounts of Co. If Co resides in the metallic phase of chondrules, Cu probably exists in the metallic phase also. The same agreement holds for the Cu-Co abundance in the five magnetic Chainpur chondrules.

Table 1

ABUNDANCES[a] OF Na, Sc, Cr, Mn, Fe, Co, AND Cu IN SELECTED METEORITES AS DETERMINED BY INAA[b]

Type of Meteorite[c]	Meteorite[d]	Mass (g)	Na (ppm)	Sc (ppm)	Cr (ppm)	Mn (ppm)	Fe[e] (%)	Co (ppm)	Cu[f] (ppm)
CHONDRITES Carbonaceous, Type II Fa, Ck	Murray	0.797	1300±20 (1690)-S2 } 1380±30[g] (1600)-EU	----- (11.3)-S1 (10.6)-S2	----- (3170)-S2 (3010)-W	1780±20 (1880)-S2 } 1800±20 (1600)-W	----- (21.3)-W [0.00]-W	----- (460)-S2 (600)-W	116±8 (D)
Fa, Ck	Santa Cruz	0.240	3910±80 (4780)-S2 } 4060±80 (3700)-W	----- (9.5)-S2	----- (3390)-S2 (2700)-W	1760±30 (1780)-S2 } 1760±30 (1500)-W	----- (19.1)-S2 (17.4)-W [0.00]-W	----- (700)-S2 (600)-W	119±12 (D) (152)-S2 } 125±18
Carbonaceous, Type III Fa, Ck	Lancé A (M) Lancé B (G)	0.871 0.721	3420±60 3320±60 } 3380±60	----- -----	----- -----	1630±20 1610±20 } 1620±20	----- -----	----- -----	118±2 (D) 127±3 (D) } 123±4
Fa, Ck	Mokoia	0.917	3430±100 (2970)-S2 } 3330±100 (3800)-EU	8.1±0.6 (12.3)-S2 (10.4)-S1 (7.9)-G	3480±70 (3500)-S2 (2280)-G (3560)-W	1360±40 (1720)-S2 } 1440±40 (1500)-W (1470)-G	24.1±0.7 (24.1)-W (22.6)-G [0.00]-W	590±20 (620)-S2 (550)-G (600)-W	106±7 (D) (77)-G
Enstatitic Fa	Abee	0.740	9230±300 (7500)-DM	7.5±0.8	3220±60	3790±80 (2000)-DM	36.9±0.9 (30.1)-DM	870±20 (700)-DM	164±9 (D) (100)-DM
L-Group Fa	Walters	0.193	7070±300 (6560)-S2	6.6±0.5 (9.0)-S2	3950±80 (3800)-S2	2450±80 (2540)-S2	22.5±0.7 (19.7)-S2	570±20 (500)-S2	144±20 (D) (83)-S2
PALLASITES Fi	Brenham	1.126	92±8 (79)-S2	-----	-----	1240±40 (1610)-S2 (1100)-E	-----	-----	54±1 (D)
Fi	Brenham	0.79[h]	-----	0.6±0.2 (1.0)-S2	160±5 (160)-S2	-----	11.8±0.9 (9.9)-S2 (8.4)-E	86±3 (5)-S1	-----
Fi	Molong	0.131	55±15	-----	-----	1270±30	-----	-----	9±2
Fi	Molong	0.015[h]	-----	0.8±0.1	144±3	-----	7.9±0.2 (8.0)-M	6±2	-----
Fi	Four Corners	0.78	1190±60	-----	-----	1090±30	-----	-----	227±10
Fi	Four Corners	0.089[h]	-----	4.4±0.4	1230±30	-----	28.7±0.5	220±10	-----

Table 1--continued

[a]Values obtained by other workers are given in parentheses and are followed by initials of workers:

S1 = Schmitt, *et al.*, Ref. 19	W = Wiik, Ref. 20	E = Eakins, Ref. 23
S2 = Schmitt and Smith, Ref. 1	G = Greenland, Ref. 21	M = Mingaye, Ref. 24
EU = Edwards and Urey, Ref. 3	DM = Dawson and Maxwell, Ref. 22	

[b]Abundances with (±) single standard deviations due to counting statistics only were calculated from peak areas of prominent gamma rays as given by a multichannel printer. Abundances with no error indication were calculated from peak heights of prominent gamma rays as plotted by a Moseley X-Y recorder and are generally accurate to better than ±10% (in most cases to ±5%). Gamma rays were: 15-h Na^{24}, 2.75 Mev; 85-d Sc^{46}, 2.01-Mev sum; 28-d Cr^{51}, 0.32 Mev; 2.56-h Mn^{56}, 0.85 Mev; 45-d Fe^{59}, 1.10 and 1.29 Mev; 5.3-y Co^{60}, 2.50-Mev sum; and 12.8-h Cu^{64}, 0.51-Mev annihilation. The dashed lines indicate that abundance values are in the process of data reduction.

[c]Fa or Fi indicates meteoritic fall or find, respectively, as given by G. T. Prior's catalogue, the Nininger Meteorite Catalogue, and the Urey and Craig tables. The classification (for example, Ck) is after Rose-Tschermak-Brezina (see Urey and Craig, Ref. 25).

[d]Replicate analyses were performed on meteoritic samples designated by "A" and "B". The parenthesized letter indicates the specimen sources, as follows: M = B. Mason and G = G. Goles.

[e]Contributions of 1.17- and 1.33-Mev γ of Co^{60} and 1.12-Mev γ of Sc^{46} were subtracted from composite peaks of Co^{60}, Sc^{46}, and 1.10 and 1.29-Mev γ of Fe^{59}. (See Ref. 1 for details.) Values in brackets indicate the metallic content obtained by other workers.

[f]Contributions of 0.51-Mev annihilation γ due to 15-h Na^{24}, the principal contributor, have been subtracted. See Ref. 1. (D) indicates the given Cu abundance is the average of two Cu values obtained with a 24-hr decay interval. Those of Murray, Santa Cruz, Lancé, and Mokoia were decayed over a 48-hr decay interval.

[g]Weighted average values are from this work and that of S2 (Ref. 1). The abundance values of this work are from different specimens than those of Ref. 1.

[h]Separated by very strong magnet.

Table 2

ABUNDANCES[a] OF Na, Sc, Cr, Mn, Fe, Co AND Cu IN AMPHOTERIC OR LL-GROUP CHONDRITES[b]

Type of Meteorite[c]	Meteorite	Mass (g)	Na (ppm)	Sc (ppm)	Cr (ppm)	Mn (ppm)	Fe[d] (%)	Co (ppm)	Cu[e] (ppm)
CHONDRITES, LL-group Fa	Ensisheim	0.249	6080±120 (7000)-MW2	8.8±0.9	4200±60 (2300)-MW2	2440±130 (2300)-MW2	26.5±1.3 (16.6)-MW2 (20.7)-UC [6.7]-UC [2.5]-MW2 [3.2]-K 21.3 Avg.	870±30 (out)[f] (600)-MW2	98±13
Fa	Jelica	0.299	6980±300 (900)-MW2	7.8±0.5	4150±80 (3400)-MW2 (4700)-UC	2470±40 (1600)-MW2 (1600)-UC	19.2±0.7 (22.7)-UC (18.3)-MW2 [1.6]-MW2 20.1 Avg.	400±10 (500)-MW2	85±19 (D)
Fa	Manbhoom	0.173	6200±300 (8000)-MW2 (3300)-UC	8.4±0.4 (8.8)-S1	3460±150 (4400)-MW2 (3800)-UC	2970±150 (2500)-MW2 (500)-UC	----- (20.9)-UC (15.8)-MW2 [0.7]-MW2 18.2 Avg.	250±10 (400)-MW2	-----
Fi	Näs	0.172	6960±300 (6200)-MW2	7.8±0.8	5740±100 (4000)-MW2	2530±40 (2700)-MW2	18.9±0.5 (16.2)-MW2 [1.5]-MW2 17.6 Avg.	440±20 (600)-MW2	90±6 (D) (98)-MW2
Fa	Vavilovka	0.314	6070±300 (10,100)-MW2 (12,000)-UC	7.8±0.4	3630±150 (2900)-MW2 (1000)-UC	3010±150 (3900)-MW2 (6000)-UC	----- (20.3)-UC (15.8)-MW2 [1.2]-MW2 18.0 Avg.	330±10 (500)-UC	-----
Grand Average of this work only			6460±410	8.1±0.4	4240±600	2690±250	19.0±1.4	350±60	91±5

Table 2--continued

[a]Values obtained by other workers are given in parentheses and are followed by initials of workers:

MW2 = Mason and Wiik, Ref. 2	K = Keil, Ref. 6
UC = Urey and Craig, Ref. 25	S1 = Schmitt, *et al.*, Ref. 19

[b]Abundances with (±) single standard deviations due to counting statistics only were calculated from peak areas of prominent gamma rays as given by a multichannel printer. Abundances with no error indication were calculated from peak heights of prominent gamma rays as plotted by a Moseley X-Y recorder and are generally accurate to better than ±10% (in most cases to ±5%). Gamma rays were: 15-h Na^{24}, 2.75 Mev; 85-d Sc^{46}, 2.01-Mev sum; 28-d Cr^{51}, 0.32 Mev; 2.56-h Mn^{56}, 0.85 Mev; 45-d Fe^{59}, 1.10 and 1.29 Mev; 5.3-y Co^{60}, 2.50-Mev sum; and 12.8-h Cu^{64}, 0.51-Mev annihilation. The dashed lines indicate that abundance values are in the process of data reduction.

[c]Fa or Fi indicates meteoritic fall or find, respectively, as given by G. T. Prior's catalogue, the Nininger Meteorite Catalogue, and the Urey and Craig tables.

[d]Contributions of 1.17- and 1.33-Mev γ of Co^{60} and 1.12-Mev γ of Sc^{46} were subtracted from composite peaks of Co^{60}, Sc^{46}, and 1.10 and 1.29-Mev γ of Fe^{59}. (See Ref. 1 for details.) Values in brackets indicate the metallic content obtained by other workers. Average values for each meteorite are the mean values for total iron of this and other work, each done on different samples. "Grand Average" for Fe is the mean of the indicated averages.

[e]Contributions of 0.51-Mev annihilation γ due to 15-h Na^{24}, the principal contributor, have been subtracted. See Ref. 1. (D) indicates the given Cu abundance is the average of two Cu values obtained with a 24-hr decay interval.

[f](out) indicates that this value was not included in the Grand Average.

Table 3

ABUNDANCES[a] OF Na, Sc, Cr, Mn, Fe, Co, AND Cu IN Ca-RICH ACHONDRITES[b]

Type of Meteorite[c]	Meteorite	Mass (g)	Na (ppm)	Sc (ppm)	Cr (ppm)	Mn (ppm)	Fe[d] (%)	Co (ppm)	Cu[e] (ppm)
ACHONDRITES Eucrites									
Fa	Haraiya	1.532	2870±150	24±1	1640±30	4110±80	14.0±0.4	2±1	6±6 (D)
Fa	Juvinas	0.252	2520±130 (3300)-UC	29±2	2100±100 (2100)-UC (1600)-G	4640±200 (1600)-UC (4040)-D	----- (14.8)-UC [Tr]-UC	4±2	-----
Fa	Moore County	0.228	3020±150 (3300)-UC (3500)-D	24±1 (23)-G	1930±100 (3020)-UC (3100)-G	3230±150 (2400)-UC (3130)-G	----- (12.2)-UC (12.7)-G	3±2 (<5)-G	-----
Fa	Nobleborough	0.514	3500±150	32±1	3280±60	4140±80	14.9±0.4	3±2	8±2 (D)
Fa	Pasamonte	1.429	2990±150 (2300)-UC	26±1	1730±30 (2100)-UC	4110±80 (3300)-UC	15.0±0.4	6±2	6±6 (D)
Fa	Sioux County	0.949	3630±120	28±1	2000±40	4110±80	19.2±0.6	3±2	10±10 (D)
Fa	Stannern	0.463	3380±160 (4500)-UC (5600)-D	32±2 (31)-S1 (48)-G	1780±100 (1920)-D (2300)-G (2400)-UC	4280±200 (3870)-D	----- (14.4)-UC [Tr]-UC	4±2	-----
Howardites									
Fa	Kapoeta (light)	0.240	1720±80	21±1	4170±200	2840±140	----- [few grains]-FK	24±2 (out)[f]	-----
Fi	Nuevo Laredo	0.177	3900±200 (4170)-D	38±2 (43)-S1 (43)-BPH	1810±100 (1990)-D (1100)-BPH	4310±200 (4300)-D	----- (15.9)-D	~2	-----
Fa	Petersburg	0.241	3000±150 (6100)-UC	29±2	2750±150	3590±160	----- (16.4)-UC [0.5]-UC	54±5 (out)[f]	-----
Grand average of this work only			3050±440	28±4	2320±650	3940±430	15.2±1.3	3±2	8±2
Average in 29 "ordinary" L-group chondrites (Table 5)			6800±600	8.7±0.9	3900±300	2670±200	21.1±2.4	540±120	109±33
Nakhlites									
Fa	Nakhla	0.270	3650±80 (3000)-UC	53±1 (54)-S (49)-G	1820±40 (2300)-UC (1900)-G	----- (3490)-G	16.4±0.6 (16.2)-UC (16.2)-G	43±4 (32)-G	-----

Table 3--continued

[a]Values obtained by other workers are given in parentheses and are followed by initials of workers:

UC = Urey and Craig, Ref. 25	Sl = Schmitt, et al., Ref. 19
G = Greenland, Ref. 21	FK = Fredriksson and Keil, Ref. 7
D = Duke, Ref. 26	BPH = Bate, Potratz, and Huizenga, Ref. 27

[b]Abundances with (±) single standard deviations due to counting statistics only were calculated from peak areas of prominent gamma rays as given by a multichannel printer. Abundances with no error indication were calculated from peak heights of prominent gamma rays as plotted by a Moseley X-Y recorder and are generally accurate to better than ±10% (in most cases to ±5%). Gamma rays were: 15-h Na^{24}, 2.75 Mev; 85-d Sc^{46}, 2.01-Mev sum; 28-d Cr^{51}, 0.32 Mev; 2.56-h Mn^{56}, 0.85 Mev; 45-d Fe^{59}, 1.10 and 1.29 Mev; 5.3-y Co^{60}, 2.50-Mev sum; and 12.8-h Cu^{64}, 0.51-Mev annihilation. The dashed lines indicate that abundance values are in the process of data reduction.

[c]Fa or Fi indicates meteoritic fall or find, respectively, as given by G. T. Prior's catalogue, the Nininger Meteorite Catalogue, and the Urey and Craig tables.

[d]Contributions of 1.17- and 1.33-Mev γ of Co^{60} and 1.12-Mev γ of Sc^{46} were subtracted from composite peaks of Co^{60}, Sc^{46}, and 1.10 and 1.29-Mev γ of Fe^{59}. (See Ref. 1 for details.) Values in brackets indicate the metallic content obtained by other workers. Grand average shown for Fe is the mean value of this and other work.

[e]Contributions of 0.51-Mev annihilation γ due to 15-h Na^{24}, the principal contributor, have been subtracted. See Ref. 1. (D) indicates the given Cu abundance is the average of two Cu values obtained with a 24-hr decay interval.

[f](out) indicates that this value was not included in the grand average..

Table 4

ABUNDANCES[a] OF Na, Sc, Cr, Mn, Fe, Co, AND Cu IN Ca-POOR ACHONDRITES[b]

Type of Meteorite[c]	Meteorite[d]	Mass (g)	Na (ppm)	Sc (ppm)	Cr (ppm)	Mn (ppm)	Fe[e] (%)	Co (ppm)	Cu[f] (ppm)
ACHONDRITES, Enstatites (aubrites)									
Fa	Bishopville A Bishopville B	0.429 0.468	6560±120 9920±200 } 8310 Avg. A (8000)-UC B (10,000)-EU	6.5±0.2 6.1±0.2 } 6.3 Avg. (11)-G	260±10 250±10 } 260 Avg. (460)-G	2200±50 800±30 } 1480 Avg. A (1140)-G B (1520)-UC	0.7±0.1 0.9±0.1 } 0.8 Avg. A (1.0)-UC B (0.6)-G	3.1±0.5 2.1±0.4 } 2.6 Avg. (8.9)-G	4±12 <10 } 7 Avg. (2.6)-G
Fa	Cumberland Falls A Cumberland Falls B	0.858 0.230	1120±50 220±20 } 930 Avg.	5.0±0.2 5.8±0.2 } 5.2 Avg.	730±20 180±10 } 620 Avg.	1470±30 860±30 } 1340 Avg.	5.6±0.2 0.05±0.10 } 4.4 Avg.	150±10 14±2 } 121 Avg.	28±11 6±2 } 23 Avg. A (D) B (D)
Fa	Norton County	0.194	450±20 (1000)-W (740)-UC	9.6±0.5 (9.0)-Sl	570±30 (500)-W (820)-UC	1710±100 (1200)-MB (1240)-W (650, 3000)-UC	----- (0.5)-UC (1.60)-W	4±2	-----
Fa	Pena Blanca Springs	0.167	1240±60	5.2±0.3	370±20	1090±50	----- (2.8)-UC	4±2	-----
Fa	Pesayanoe	0.488	3410±60	8.5±0.2	470±10	1040±30	1.2±0.2	57±3	15±5 (D)
Average			2900±2400	7.0±1.6	460±110	1330±210	2.1±1.5	38±41	15±5
Olivine pigeonites (ureilites)	Novo-Urei	0.333	520±30 (3300)-R	8.8±0.4	5050±100 (3100)-Cr	3050±60 (2800)-R	15.3±0.3 (15.6)-R	123±6	9±1 (D)

[a]Values obtained by other workers are given in parentheses and are followed by initials of workers:

EU = Edwards and Urey, Ref. 3; UC = Urey and Craig, Ref. 25; G = Greenland, Ref. 21; W = Wiik, Ref. 20; Sl = Schmitt, et al., Ref. 19; MB = Moore and Brown, Ref. 28; R = Ringwood, Ref. 29; Cr = Craig, Ref. 30

[b]Abundances with (±) single standard deviations due to counting statistics only were calculated from peak areas of prominent gamma rays as given by a multichannel printer. Abundances with no error indication were calculated from peak heights of prominent gamma rays as plotted by a Moseley X-Y recorder and are generally accurate to better than ±10% (in most cases to ±5%). Gamma rays were: 15-h Na^{24}, 2.75 Mev; 85-d Sc^{46}, 2.01-Mev sum; 28-d Cr^{51}, 0.32 Mev; 2.56-h Mn^{56}, 0.85 Mev; 45-d Fe^{59}, 1.10 and 1.29 Mev; 5.3-y Co^{60}, 2.50-Mev sum; and 12.8-h Cu^{64}, 0.51-Mev annihilation. The dashed lines indicate that abundance values are in the process of data reduction.

[c]Fa or Fi indicates meteoritic fall or find, respectively, as given by G. T. Prior's catalogue, the Nininger Meteorite Catalogue, and the Urey and Craig tables.

[d]Replicate analyses were performed on meteoritic samples designated by "A" and "B".

[e]Contributions of 1.17- and 1.33-Mev γ of Co^{60} and 1.12-Mev γ of Sc^{46} were subtracted from composite peaks of Co^{60}, Sc^{46}, and 1.10 and 1.29-Mev γ of Fe^{59}. (See Ref. 1 for details.)

[f]Contributions of 0.51-Mev annihilation γ due to 15-h Na^{24}, the principal contributor, have been subtracted. See Ref. 1. (D) indicates the given Cu abundance is the average of two Cu values obtained with a 24-hr decay interval.

Table 5

AVERAGE METEORITIC AND TERRESTRIAL ABUNDANCES OF Na, Sc, Cr, Mn, Fe, Co, AND Cu[a]

Type of Meteorite	Na (ppm) ($\times 10^3$)	Na atoms/ 10^6 Si atoms ($\times 10^3$)	Sc (ppm)	Sc atoms/ 10^6 Si atoms	Cr (ppm) ($\times 10^3$)	Cr atoms/ 10^6 Si atoms ($\times 10^3$)	Mn (ppm) ($\times 10^3$)	Mn atoms/ 10^6 Si atoms ($\times 10^3$)	Fe[b] (%)	Fe atoms/ 10^6 Si atoms ($\times 10^5$)	Co (ppm)	Co atoms/ 10^6 Si atoms	Cu (ppm)	Cu atoms/ 10^6 Si atoms
Chondritic														
Carbonaceous														
2 Type I	5.3 ±0.2[c]	61 ±2	5.3 ±0.2	32 ±1	2.6 ±0.2	13.2 ±1.1	1.82 ±0.07	8.8 ±0.3	17.7 ±0.9	8.4 ±0.5	500 ±30	2230 ±120	118 ±1	490 ±10
4 Type II	4.0 ±0.3	38 ±2	9.4 ±0.9	44 ±2	3.1 ±0.2	12.8 ±0.4	1.73 ±0.08	6.7 ±0.4	20.4 ±1.4	-----	550 ±70	2000 ±200	121 ±1	400 ±10
7 Type III	3.6 ±0.6	28 ±6	10.5 ±0.8	42 ±7	3.5 ±0.1	12.0 ±0.4	1.63 ±0.12	5.6 ±0.3	22.4 ±3.2	-----	610 ±80	1820 ±180	116 ±26	350 ±30
20 H-group ordinary[d]	6.2 ±0.5	45 ±3	8.3 ±1.0	31 ±4	4.0 ±0.3	12.7 ±1.0	2.43 ±0.13	7.3 ±0.5	25.9 ±2.1 [15]	7.7 ±0.6	860 ±90 [16]	2410 ±250	100 ±10 [19]	260 ±30
29 L-group ordinary[d]	6.8 ±0.6	45 ±4	8.7 ±0.9	29 ±3	3.9 ±0.3	11.2 ±0.9	2.67 ±0.22 [28]	7.4 ±0.6	21.1 ±2.4 [19]	5.8 ±0.7	540 ±120 [24]	1390 ±300	109 ±33 [24]	260 ±80
5 LL-group amphoterites	6.5 ±0.4	---	8.1 ±0.4	---	4.2 ±0.6	-----	2.69 ±0.25	-----	19.0 ±1.4	-----	350 ±60	-----	91 ±5	-----
4 Enstatites	7.1 ±1.2	---	7.5 ±1.6	---	-----	-----	2.85 ±0.47	-----	30.5 ±3.0	-----	870 ±70	-----	148 ±16	370 ±60
Nonchondritic														
10 Ca-rich achondrites[e]	3.0 ±0.4	16 ±2	28 ±4	77 ±11	2.3 ±0.7	5.5 ±1.5	3.9 ±0.4	8.8 ±1.0	(15.2 ±1.3) UC, D	3.4 ±0.3	3 ±1	6 ±2	8 ±2	-----
5 Ca-poor achondrites	2.8 ±2.4	---	7.0 ±1.6	---	0.42 ±0.09	-----	1.3 ±0.2	-----	1.7 ±0.9	-----	35 ±33	-----	13 ±4	-----
2 Mesosiderites	1.5 ±0.2	---	16 ±1	---	3.5 ±2.0	-----	2.8 ±0.7	-----	9 to 39	-----	45 to 1290	-----	-----	-----
4 Pallasites	0.095 ±0.017	---	1.4 ±0.2	---	0.28 ±0.08	-----	2.0 ±0.2	-----	-----	-----	7 ±2	-----	-----	-----
Terrestrial specimens														
4 Basalts	16.6 ±3.1	---	38 ±7	---	<0.1 to 1.2	-----	2.5 ±0.4	-----	9.2 ±0.2	-----	51 ±9	-----	-----	-----
2 Eclogites	7.8 ±2.6	---	47 ±3	---	1.4 ±0.9	-----	2.6 ±0.1	-----	-----	-----	53 ±6	-----	-----	-----
2 Peridotites	0.9 ±0.5	---	13 ±1	---	2.7 ±0.1	-----	1.1 ±0.1	-----	-----	-----	110 ±10	-----	-----	-----
1 Kimberlite	1.0	---	12	---	1.6	-----	1.0	-----	-----	-----	82	-----	-----	-----

[a] Average values calculated from INAA values of this work given in Tables 1 through 4.
[b] Values obtained by other workers are given in parentheses, accompanied by initials of workers: UC = Urey and Craig, Ref. 25; D = Duke, Ref. 26.
[c] Only Orgueil and Ivuna constitute average for Type I carbonaceous meteorites.
[d] Where less than 20 H- and 29 L-group chondrites are averaged, the number in brackets indicates the actual number of chondrites used to obtain the average value.
[e] Nakhla has been excluded.

Table 6

AVERAGE ABUNDANCES OF Na IN CHONDRULES

Chondritic Meteorite	Number of Chondrules[a]	Chondrule Mass Range (mg)	$\overline{Na}$ (ppm)		Na (Chondrite) (ppm)	Ratio of $\overline{Na}$(chondrules) to Na(chondrite)
			Chondrules	All Chondrules		
Santa Cruz (Type II)	8	0.1 - 0.6	860 ±150	1010 ±250 (±25%)	3910 ±80	0.26
	3	2.3 - 3.6	1390 ±50			
Lancé (Type III)	11 (m)	0.1 - 0.4	5640 ±1840	5910 ±1870 (±32%)	3380 ±70	1.75
	9 (m)	0.5 - 2.1	6200 ±1890			
Mokoia (Type III)	6 (m)	0.4 - 1.0	2910 ±1460	2290 ±990 (±45%)	3330 ±120	0.69
	14 (m)	1 - 6	2020 ±810			
	5 (m)	6 - 71	2280 ±800			
Chainpur (Type III)	5 (m)	1 - 14	6360 ±2150	6540 ±1690 (±26%)	7470 ±150	0.88
	6	1 - 5	6550 ±1320			
	9	5 - 31	6660 ±1540			
Allegan (H) (Ordinary)	8	0.4 - 1.0	7110 ±1260	7250 ±1160 (±13%)	5730 ±260	1.27
	11	1.0 - 4	7350 ±1000			
Ochansk (H) (Ordinary)	5 (m)	7 - 21	5510 ±480	7080 ±1240 (±18%)	6190 ±120	1.15
	5	0.3 - 0.7	7680 ±1180			
	5	1.8 - 3.0	8220 ±1320			
	5	5 - 8	6810 ±620			
Bjurböle (L) (Ordinary)	13	0.5 - 1.0	8380 ±1630	8450 ±1200 (±14%)	6980 ±150	1.21
	17	1.0 - 1.7	8550 ±860			

[a] Nonmagnetic, unless specified with (m).

Table 7

AVERAGE ABUNDANCES OF Sc IN CHONDRULES

Chondritic Meteorite	Number of Chondrules[a]	Chondrule Mass Range (mg)	$\overline{Sc}$ (ppm)		Sc (Chondrite) (ppm)	Ratio of $\overline{Sc}$(chondrules) to Sc(chondrite)
			Chondrules	All Chondrules		
Mokoia (Type III)	6 (m)	0.4 - 1.0	12.0 ±3.0	10.5 ±2.9	8.8 ±0.8	1.19
	14 (m)	1 - 6	9.1 ±2.8			
	5 (m)	6 - 71	12.5 ±1.4			
Chainpur (Type III)	5 (m)	1 - 14	9.1 ±1.0	9.8 ±2.6	10.4 ±0.5	0.94
	6	1 - 5	11.6 ±4.3			
	9	5 - 31	8.9 ±2.2			
Allegan (H) (Ordinary)	8	0.4 - 1.0	12.0 ±3.9	11.9 ±4.2	8.1 ±0.6	1.47
	12	1.0 - 4	9.5 ±3.9			
Ochansk (H) (Ordinary)	5 (m)	7 - 21	11.3 ±1.3	12.3 ±3.6	9.4 ±0.6	1.31
	5	0.3 - 0.7	12.0 ±5.6			
	5	1.8 - 3.0	11.5 ±2.6			
	5	5 - 8	14.5 ±4.0			
Bjurböle (L) (Ordinary)	13	0.5 - 1.0	11.1 ±1.9	11.1 ±2.4	8.6 ±0.5	1.29
	17	1.0 - 1.7	11.1 ±2.8			

[a]Nonmagnetic, unless specified with (m).

Table 3

AVERAGE ABUNDANCES OF Cr IN CHONDRULES

Chondritic Meteorite	Number of Chondrules[a]	Chondrule Mass Range (mg)	$\overline{Cr}$ (ppm)		Cr (Chondrite) (ppm)	Ratio of $\overline{Cr}$(chondrules) to Cr(chondrite)
			Chondrules	All Chondrules		
Mokoia (Type III)	6 (m)	0.4 - 1.0	3420 ±680	3260 ±670	3480 ±90	0.94
	14 (m)	1 - 6	3190 ±780			
	5 (m)	6 - 71	3260 ±350			
Chainpur (Type III)	5 (m)	1 - 14	3770 ±650	3980 ±380	3450 ±40	1.15
	6	1 - 5	4130 ±450			
	9	5 - 31	3990 ±220			
Allegan (H) (Ordinary)	8	0.4 - 1.0	2380 ±570	2600 ±610	3640 ±150	0.71
	12	1 - 4	2760 ±530			
Ochansk (H) (Ordinary)	5 (m)	7 - 21	2750 ±340	2660 ±530	3900 ±50	0.68
	5	0.3 - 0.7	2220 ±720			
	5	1.8 - 3.0	2610 ±550			
	5	5 - 8	3050 ±390			
Bjurböle (L) (Ordinary)	12	0.5 - 1.0	2980 ±650	3130 ±650	3650 ±40	0.86
	17	1.0 - 1.7	3230 ±640			

[a]Nonmagnetic, unless specified with (m).

Table 9

AVERAGE ABUNDANCES OF Mn IN CHONDRULES

Chondritic Meteorite	Number of Chondrules[a]	Chondrule Mass Range (mg)	$\overline{Mn}$ (ppm) Chondrules	$\overline{Mn}$ (ppm) All Chondrules	Mn (Chondrite) (ppm)	Ratio of $\overline{Mn}$(chondrules) to Mn(chondrite)
Santa Cruz (Type II)	8	0.1 - 0.6	1150 ±190	1170 ±160 (±16%)	1760 ±30	0.67
	3	2.3 - 3.6	1230 ±70			
Lancé (Type III)	11 (m)	0.1 - 0.4	1000 ±210	1090 ±360 (±35%)	1620 ±30	0.67
	9 (m)	0.5 - 2.1	1190 ±540			
Mokoia (Type III)	6 (m)	0.4 - 1.0	990 ±260	800 ±270 (±34%)	1440 ±60	0.56
	12 (m)	1 - 6	690 ±240			
	5 (m)	6 - 71	850 ±210			
Chainpur (Type III)	5 (m)	1 - 14	1650 ±830	2940 ±980 (±33%)	2790 ±110	1.06
	6	1 - 5	3800 ±370			
	9	5 - 31	2960 ±820			
Allegan (H) (Ordinary)	8	0.4 - 1.0	2980 ±140	2970 ±160 (±5%)	2380 ±110	1.25
	10	1.0 - 4	2960 ±170			
Ochansk (H) (Ordinary)	5 (m)	7 - 21	2870 ±180	2970 ±180 (±6%)	2400 ±120	1.24
	5	0.3 - 0.7	3030 ±210			
	5	1.8 - 3.0	2950 ±130			
	5	5 - 8	3020 ±190			
Bjurböle (L) (Ordinary)	13	0.5 - 1.0	2900 ±200	2940 ±150 (±5%)	2860 ±140	1.03
	17	1.0 - 1.7	2990 ±120			

[a]Nonmagnetic, unless specified with (m).

Table 10

AVERAGE ABUNDANCES OF Fe IN CHONDRULES

Chondritic Meteorite	Number of Chondrules[a]	Chondrule Mass Range (mg)	$\overline{Fe}$ (ppm) Chondrules	$\overline{Fe}$ (ppm) All Chondrules	Fe (Chondrite) (ppm)	Ratio of $\overline{Fe}$(chondrules) to Fe(chondrite)
Mokoia (Type III)	6 (m)	0.4 - 1.0	8.2 ±5.2	9.6 ±5.2	24.1 ±0.7	0.40
	12 (m)	1 - 6	9.6 ±5.7			
	5 (m)	6 - 71	11.3 ±4.2			
Chainpur (Type III)	5 (m)	1 - 14	14.2 ±4.8	10.3 ±4.3	16.7 ±0.5	0.62
	6	1 - 5	5.9 ±1.9			
	9	5 - 31	11.1 ±3.6			
Allegan (H) (Ordinary)	8	0.4 - 1.0	7.7 ±1.9	8.2 ±2.2	29.8 ±1.9	0.28
	12	1.0 - 4	8.5 ±2.4			
Ochansk (H) (Ordinary)	5 (m)	7 - 21	8.9 ±1.6	7.0 ±2.2	25.5 ±1.1	0.27
	5	0.3 - 0.7	3.9 ±1.7			
	5	1.8 - 3.0	6.6 ±1.4			
	5	5 - 8	8.4 ±1.9			
Bjurböle (L) (Ordinary)	13	0.5 - 1.0	10.7 ±1.6	10.6 ±1.8	21.6 ±0.8	0.49
	17	1.0 - 1.7	10.4 ±1.9			

[a]Nonmagnetic, unless specified with (m).

Table 11

AVERAGE ABUNDANCES OF Co IN CHONDRULES

Chondritic Meteorite	Number of Chondrules[a]	Chondrule Mass Range (mg)	$\overline{Co}$ (ppm) Chondrules	$\overline{Co}$ (ppm) All Chondrules	Co (Chondrite) (ppm)	Ratio of $\overline{Co}$(chondrules) to Co(chondrite)
Mokoia (Type III)	6 (m)	0.4 - 1.0	280 ±110	350 ±170	600 ±30	0.58
	14 (m)	1 - 6	370 ±190			
	5 (m)	6 - 71	390 ±160			
Chainpur (Type III)	5 (m)	1 - 14	620 ±230	260 ±217	490 ±10	0.53
	6	1 - 5	117 ±65			
	9	5 - 31	146 ±119			
Allegan (H) (Ordinary)	8	0.4 - 1.0	48 ±32	46 ±26	900 ±110	0.051
	12	1 - 4	45 ±22			
Ochansk (H) (Ordinary)	5 (m)	7 - 21	84 ±40	~39 ±22	750 ±40	~0.052
	5	0.3 - 0.7	32 ±12			
	5	1.8 - 3.0	~15 ±13			
	5	5 - 8	~26 ±21			
Bjurböle (L) (Ordinary)	13	0.5 - 1.0	21 ±16	37 ±34	520 ±20	0.071
	17	1.0 - 1.7	50 ±42			

[a]Nonmagnetic, unless specified with (m).

Table 12

AVERAGE ABUNDANCES OF Cu IN CHONDRULES

Chondritic Meteorite	Number of Chondrules[a]	Chondrule Mass Range (mg)	$\overline{Cu}$ (ppm) Chondrules	$\overline{Cu}$ (ppm) All Chondrules	Cu (Chondrite) (ppm)	Ratio of $\overline{Cu}$(chondrules) to Cu(chondrite)
Santa Cruz (Type II)	8	0.1 - 0.6	55 ±29	51 ±25	125 ±18	0.41
	3	2.3 - 3.5	39 ±5			
Lancé (Type III)	11 (m)	0.1 - 0.4	87 ±46	79 ±46	123 ±4	0.65
	9 (m)	0.5 - 2.1	69 ±46			
Mokoia (Type III)	6 (m)	0.4 - 1.0	74 ±27	70 ±40 (±57%)	106 ±7	0.66
	12 (m)	1 - 6	67 ±48			
	5 (m)	6 - 71	77 ±32			
Chainpur (Type III)	5 (m)	1 - 14	88 ±33	34 ±34 (±100%)	62 ±9	0.55
	15	1 - 31	16 ±16			
Allegan (H) (Ordinary)	5	0.4 - 1.0	<28 - 57	~29 ±21	105 ±20	~0.28
	7	1.3 - 4.0	27 ±17			
Ochansk (H) (Ordinary)	5 (m)	7 - 21	66 ±25	59 ±19	93 ±8	0.64
	5	5 - 8	51 ±13			
Bjurböle (L) (Ordinary)	8	0.5 - 1.0	<13 - 186	~75 ±45	178 ±16	~0.42

[a]Nonmagnetic, unless specified with (m).

Table 13

ABUNDANCES OF Na, Sc, Cr, Mn, Fe, Co, AND Cu IN INDIVIDUAL CHONDRULES OF ALLEGAN (BRONZITIC CHONDRITE) DETERMINED BY INAA[a]

Allegan Chondrule	Mass (mg)	Na (ppm)	Sc (ppm)	Cr (ppm)	Mn (ppm)	Fe (%)	Co (ppm)	Cu (ppm)
1	0.440	5590±180	11.1±1.1	2180±220	3130±60	7.5±0.8	66±7	57±24
2	0.444	9100	10.1±1.0	3440±300	3100	6.3±0.6	51±5	<28
3	0.521	9460	10.6±1.2	2040±200	2930	5.3±0.5	131±14	<30
4	0.570	7350	19.7±1.8	2160±160	2890	6.4±1.0	3±5	-----
5	0.625	5440	4.1±0.8	2080±160	3240	8.5±0.8	41±6	-----
6	0.856	7050	9.2±0.5	2050±40	2840	10.5±0.3	23±5	-----
7	0.885	7630	11.6±0.7	3560±70	2700	11.9±0.6	<3	50±19
8	0.915	5280	20±1.5	1470±30	2970	5.4±1.3	70±15	53±17
Average		7110±1260	12.0±3.9	2380±570	2980±140	7.7±1.9	48±15	
9	1.035	(15,000)	4.4±0.6	2920±60	2590	6.8±0.7	37±7	-----
10	1.125	(10,200)	7.0±0.5	2220±40	2800	6.4±0.6	33±6	-----
11	1.225	7500	26±1	2210±40	2890	5.0±0.4	7±3	-----
12	1.270	8400	10.8±0.5	2540±50	3130	6.0±0.5	17±6	-----
13	1.305	7800	10.7±0.6	2960±60	3130	6.0±0.6	49±6	10±15
14	1.33	(3620)	9.2±0.7	3410±70	3110	10.5±0.6	80±9	47±12
15	1.49	6730	10.5±0.6	3080±60	3130	6.1±0.5	26±5	3±15
16	1.75	5900	9.6±1.3	3020±40	3130	10.9±1.6	35±28	48±12
17	2.33	7930	10.5±1.0	3830±40	3040	8.5±1.1	59±18	
18	2.71	7830	16.2±1.0	3300±30	2680	10.0±0.6	94±15	12±12
19	2.97	7760	7.6±0.8	1490±20	2800	15.2±0.3	72±14	46±11
20	3.93	7050	19.3±0.8	2100±30	3070	10.2±0.5	27±12	21±10
Average		7710±730	9.5±3.9	2760±530	2960±170	8.5±2.4	45±22	29±17
Over-all average		7450±1020	11.9±4.2	2600±610	2970±150	8.2±2.2	46±26	~29±21
Whole chondrite	1730	5730±260	8.1±0.6	3640±150	2380±110	29.8±1.9	900±110	105±20

[a]Abundances were calculated from peak areas of principal gamma rays as given by a multichannel printer. Errors are one standard deviation due to counting statistics only. For Na, Cr, and Mn, the errors of individual analyses are all approximately ±2% to 3%. Values in parentheses are not included in averages.

Table 14

ABUNDANCES OF Na, Sc, Cr, Mn, Fe, Co, AND Cu IN INDIVIDUAL CHONDRULES OF OCHANSK (BRONZITIC CHONDRITE) DETERMINED BY INAA[a]

Ochansk Chondrule[b]	Mass (mg)	Na (ppm)	Sc (ppm)	Cr (ppm)	Mn (ppm)	Fe (%)	Co (ppm)	Cu (ppm)
1	0.275	(19,700)±400	24.2±1.5	2280±130	2400±50	1.6±1.0	21±21	-----
2	0.288	8450	6.8±0.7	2610±50	3130	3.2±0.5	41±10	-----
3	0.412	7310	13.8±1.4	960±100	3250	2.8±0.3	18±12	-----
4	0.612	9280	9.1±1.0	3580±70	3020	6.8±1.2	35±12	-----
5	0.679	5650	6.1±0.8	1690±40	3370	5.3±0.9	47±12	-----
Average		7680±1180	12.0±5.6	2220±720	3030±210	3.9±1.7	32±12	
6	1.79	8310	7.8±0.6	3850±80	3080	7.4±0.4	<2	-----
7	2.54	8070	11.7±0.5	2840±60	2690	7.8±0.6	30±5	-----
8	2.63	7210	17.8±0.8	1990±80	2900	7.5±0.3	28±4	-----
9	2.93	6110	9.7±0.5	2410±100	3140	5.6±0.4	25±5	-----
10	2.93	(11,400)	10.6±0.4	1940±40	2920	4.5±0.3	5±3	-----
Average		7430±770	11.5±2.6	2610±550	2950±130	6.6±1.4	15±13	
11	5.51	7040	20.7±1.0	2550±60	2860	8.4±0.7	<7	35±21
12	6.09	5870	14.4±0.7	3550±40	3010	4.6±0.6	32±5	55±17
13	6.45	6210	9.1±2.2	2800±60	2950	13.0±0.9	<40	35±17
14	7.27	7070	9.9±0.6	3530±40	3480	7.7±0.6	42±6	68±19
15	7.66	7890	18.2±1.0	2840±50	2780	8.4±0.6	58±6	61±22
Average		6810±620	14.5±4.0	3050±390	3020±190	8.4±1.9	26±21	51±13
16 (m)	6.8	4920	13.6±0.8	2570±50	3110	5.9±0.6	60±7	50±18
17 (m)	10.5	4860	11.9±0.5	2100±40	2660	7.8±0.4	54±5	29±14
18 (m)	13.7	5830	10.0±0.5	3340±60	2740	10.2±0.4	103±8	84±14
19 (m)	16.7	5630	9.2±0.5	2740±60	3060	10.3±0.3	38±4	109±13
20 (m)	20.5	6270	11.7±0.7	3020±60	2760	10.2±0.5	165±11	59±14
Average		5510±490	11.3±1.3	2750±340	2870±180	8.9±1.6	84±40	66±24
Over-all average		6820±1070	12.3±3.6	2660±530	2970±180	7.0±2.2	39±22	59±19
Whole chondrite	307	6190±120	8.9±0.5	3840±40	2400±120	28.4±1.0	710±20	93±8

[a]See footnote (a) of Table 13.
[b]Magnetic chondrule indicated with (m).

Table 15

ABUNDANCES OF Sc, Cr, Fe, AND Co IN INDIVIDUAL CHONDRULES OF BJURBÖLE (HYPERSTHENIC CHONDRITE) DETERMINED BY INAA[a]

Bjurböle Chondrule	Sc (ppm)	Cr (ppm)	Fe (%)	Co (ppm)
1	11.5±0.6	2420±50	7.7±0.4	15±5
2	14.3±0.7	2680±60	8.2±0.6	14±6
3	14.5±0.5	2300±50	9.5±0.6	7±6
4	8.1±0.6	4460±180	15.1±0.7	63±8
5	5.0±0.6	(10,700±200)	14.0±0.9	79±8
6	11.1±0.5	2560±50	11.6±0.6	6±6
7	12.1±0.5	4350±80	10.2±0.5	8±4
8	8.4±0.4	2980±60	11.3±0.4	5±4
9	14.2±0.5	3900±80	9.4±0.6	7±5
10	11.4±0.6	3070±60	9.0±0.8	15±6
11	11.3±0.5	2540±50	11.5±0.4	18±6
12	10.9±0.8	2220±150	11.4±0.7	22±8
13	12.2±0.5	2280±50	10.8±0.6	10±6
Average	11.1±1.9	2980±650	10.7±1.6	21±16
14	11.1±0.4	2810±60	9.3±1.6	94±5
15	13.5±0.9	2690±150	5.8±0.6	27±7
16	13.2±0.8	2620±130	9.1±0.7	37±10
17	4.5±0.6	3090±150	20.8±1.0	83±10
18	13.9±0.6	2600±50	10.7±2.0	12±4
19	14.1±0.5	3050±60	11.0±0.4	4±3
20	14.2±0.4	2000±40	10.7±0.5	10±3
21	8.0±0.6	3630±150	6.9±0.5	54±7
22	6.9±0.7	5310±200	7.5±0.6	103±10
23	14.2±0.4	3950±80	10.5±1.1	8±4
24	9.1±0.4	3390±70	10.7±0.5	60±5
25	11.7±0.9	2730±120	10.4±0.6	108±12
26	14.5±0.5	3090±60	9.6±0.6	18±6
27	6.6±0.5	2740±120	9.5±0.5	1±8
28	7.7±0.4	4070±80	9.1±0.5	13±4
29	14.1±0.4	2700±60	12.9±0.5	15±4
30	11.7±0.8	4450±170	12.5±0.7	206±15
Average	11.1±2.8	3230±640	10.4±1.9	50±42
Over-all average	11.1±2.4	3130±650	10.6±1.8	37±34
Whole chondrite	8.6±0.5	3650±40	21.6±0.8	520±20

[a]See footnote (a) of Table 13.

Table 16

ABUNDANCES OF Na, Sc, Cr, Mn, Fe, Co, AND Cu IN INDIVIDUAL CHONDRULES OF MOKOIA (TYPE III CARBONACEOUS CHONDRITE) DETERMINED BY INAA[a]

Mokoia Chondrule	Mass (mg)	Na (ppm)	Sc (ppm)	Cr (ppm)	Mn (ppm)	Fe (%)	Co (ppm)	Cu (ppm)
1	0.35	720 ±50	13.0 ±2.2	2720 ±60	1300 ±20	17.4 ±3.0	250 ±50	75 ±25 (D)
2	0.35	4400 ±70	20.5 ±2.3	3540 ±70	710 ±10	2.3 ±2.5	260 ±50	70 ±20
3	0.61	1830 ±50	9.2 ±1.5	3620 ±70	950 ±10	10.7 ±1.8	410 ±30	100 ±15
4	0.67	1820 ±40	9.4 ±1.0	3580 ±70	970 ±10	3.8 ±1.0	260 ±30	60 ±15
5	0.72	3190 ±60	11.0 ±1.0	2090 ±40	570 ±10	2.9 ±1.2	34 ±21	11 ±15
6	0.92	5500 ±80	8.9 ±1.1	4980 ±100	1450 ±10	12.0 ±1.5	490 ±30	126 ±20
Average		2910 ±1460	12.0 ±3.0	3420 ±680	990 ±260	8.2 ±5.2	280 ±110	74 ±27
7	1.09	5880 ±70	7.2 ±0.9	5790 ±120	(3630 ±20)	3.7 ±1.0	6 ±17	0
8	1.32	2100 ±50	15.4 ±1.0	3840 ±80	840 ±10	5.7 ±0.6	8 ±14	9 ±9
9	1.35	1530 ±40	8.9 ±1.3	1800 ±40	300 ±10	1.7 ±0.8	270 ±30	38 ±10
10	1.36	390 ±10	3.6 ±0.6	1300 ±30	310 ±10	2.1 ±0.7	53 ±13	5 ±3
11	1.48	1450 ±30	4.4 ±1.5	4020 ±80	(4050 ±20)	21.0 ±1.7	760 ±40	246 ±24 (D)
12	1.70	1280 ±30	4.8 ±1.0	2510 ±50	230 ±10	4.0 ±1.3	290 ±30	31 ±8
13	2.67	1960 ±40	15.5 ±1.3	3430 ±70	670 ±10	10.9 ±1.0	410 ±20	78 ±3 (D)
14	2.78	2750 ±60	8.2 ±1.2	3310 ±60	740 ±10	14.2 ±1.4	490 ±30	93 ±14
15	2.96	2260 ±40	11.5 ±1.2	3110 ±60	490 ±10	6.6 ±0.8	360 ±20	43 ±10
16	3.00	1180 ±30	7.3 ±1.0	2620 ±80	680 ±10	3.3 ±1.1	310 ±30	60 ±10
17	3.36	1830 ±40	8.7 ±1.2	2360 ±50	690 ±10	10.8 ±0.9	370 ±20	43 ±8
18	3.41	1130 ±30	8.9 ±1.8	3350 ±70	940 ±10	22.3 ±1.5	720 ±40	113 ±7 (D)
19	4.53	1800 ±40	12.7 ±1.6	3690 ±70	1560 ±20	11.1 ±1.4	660 ±30	133 ±3 (D)
20	5.23	2800 ±40	10.3 ±1.5	3490 ±70	780 ±10	16.9 ±1.4	520 ±30	38 ±13
Average		2020 ±810	9.1 ±2.8	3190 ±780	690 ±240	9.6 ±5.7	370 ±190	67 ±48
21	6.57	1910 ±40	15.7 ±2.0	2500 ±50	550 ±10	5.5 ±0.6	270 ±40	39 ±8
22	8.49	1480 ±30	12.7 ±1.6	3480 ±70	830 ±10	9.1 ±1.0	460 ±30	79 ±12
23	17.3	1450 ±30	11.5 ±1.2	3170 ±60	900 ±10	18.9 ±1.3	720 ±30	138 ±2 (D)
24	22.3	4160 ±60	10.1 ±0.8	3890 ±80	650 ±10	8.8 ±0.7	350 ±20	92 ±1 (D)
25	70.8	2400 ±30	12.3 ±0.6	3290 ±60	1320 ±10	14.3 ±0.4	140 ±10	34 ±4 (D)
Average		2280 ±800	12.5 ±1.4	3260 ±350	850 ±210	11.3 ±4.2	390 ±160	
Over-all average		2290 ±990	10.5 ±2.9	3260 ±670	800 ±270	9.6 ±5.2	350 ±170	70 ±40
Whole-rock matrix	1180	3330 ±120	8.8 ±0.8	3480 ±90	1440 ±60	24.1 ±0.7	600 ±30	106 ±7

[a]See footnote (a) of Table 13.

Table 17

ABUNDANCES OF Na, Mn, AND Cu IN INDIVIDUAL CHONDRULES OF LANCÉ (TYPE III CARBONACEOUS CHONDRITE) AS DETERMINED BY INAA[a]

Lancé Chondrule	Mass (mg)	Na (ppm)	Mn (ppm)	Cu (ppm)
1	0.092	(24,800 ±500)	790 ±20	170 ±58
2	0.095	2650 ±50	930 ±20	28 ±17
3	0.127	3010 ±90	1210 ±30	5 ±15
4	0.183	5510 ±100	1520 ±30	74 ±24
5	0.223	8100 ±160	580 ±10	136 ±23
6	0.245	5850 ±100	830 ±20	83 ±38 (D)
7	0.282	3600 ±70	1460 ±30	18 ±14 (D)
8	0.285	6500 ±80	1000 ±20	78 ±6 (D)
9	0.303	4230 ±80	900 ±20	69 ±4 (D)
10	0.345	10,200 ±200	930 ±20	208 ±20 (D)
11	0.357	6780 ±130	910 ±20	89 ±31 (D)
Average		5640 ±1840	1000 ±210	87 ±46
12	0.51	7730 ±150	880 ±20	144 ±28 (D)
13	0.53	5030 ±100	1800 ±40	88 ±18 (D)
14	0.64	7580 ±140	2180 ±40	10 ±10 (D)
15	0.81	2590 ±1002	900 ±20	4 ±4 (D)
16	0.96	7120 ±140	2050 ±40	20 ±1 (D)
17	1.07	10,870 ±200	850 ±20	55 ±15 (D)
18	1.76	5650 ±100	590 ±10	108 ±2 (D)
19	2.09	4600 ±90	930 ±20	141 ±12 (D)
20	2.09	4600 ±90	550 ±10	52 ±2 (D)
Average		6200 ±1890	1190 ±540	69 ±46
Over-all average		5910 ±1870	1090 ±360	79 ±46
Whole chondrite	1592	3380 ±70	1620 ±20	

[a]See footnote (a) of Table 13.

Table 18

ABUNDANCES OF Na, Sc, Cr, Mn, Fe, Co, AND Cu IN INDIVIDUAL CHONDRULES OF CHAINPUR (TYPE III CARBONACEOUS CHONDRITE) DETERMINED BY INAA[a]

Chainpur Chondrule[b]	Mass (mg)	Na (ppm)	Sc (ppm)	Cr (ppm)	Mn (ppm)	Fe (%)	Co (ppm)	Cu (ppm)
1 (m)	1.44	3740 ±80	8.9 ±1.5	3000 ±180	1370 ±30	7.1 ±1.6	500 ±40	68 ±12
2 (m)	2.05	8290	8.3 ±1.6	4010 ±160	2360	14.9 ±1.5	500 ±40	83 ±14
3 (m)	3.57	9680	9.8 ±1.0	4170 ±200	3030	9.3 ±1.2	280 ±30	62 ±12
4 (m)	6.95	6480	10.9 ±1.4	4770 ±250	680	16.8 ±1.7	860 ±50	56 ±7
5 (m)	14.08	3590	7.5 ±0.9	2910 ±150	830	22.9 ±1.2	960 ±60	172 ±8
Average		6360 ±2150	9.1 ±1.0	3770 ±650	1650 ±830	14.2 ±4.8	620 ±230	88 ±33
6	1.06	5480	6.1 ±0.9	3460 ±70	4460	7.1 ±0.8	92 ±15	17 ±14
7	2.05	6120	21.6 ±1.9	3870 ±240	3750	8.6 ±1.7	97 ±32	3 ±9
8	2.42	3980	14.4 ±1.5	3670 ±190	3480	3.0 ±1.8	115 ±38	8 ±8
9	2.45	10,100	10.4 ±1.2	4270 ±200	3950	3.2 ±1.1	49 ±25	0
10	2.72	7460	8.5 ±0.9	4900 ±250	4000	5.7 ±0.9	37 ±19	9 ±12
11	3.38	6160	8.5 ±1.5	4550 ±200	3160	7.8 ±1.9	310 ±30	51 ±10
Average		6550 ±1320	11.6 ±4.3	4130 ±450	3800 ±370	5.9 ±1.9	117 ±65	
12	5.10	7680	5.6 ±0.5	4110 ±200	1640	5.0 ±0.4	45 ±8	0
13	5.82	7290	13.2 ±1.0	3950 ±200	2010	9.7 ±0.9	420 ±30	0
14	5.97	5480	9.1 ±0.7	4120 ±200	3950	12.2 ±1.0	54 ±14	64 ±12
15	6.62	9310	8.2 ±0.9	4400 ±200	3840	6.0 ±0.5	26 ±18	0
16	7.14	7120	6.3 ±1.0	3940 ±200	2940	20.0 ±1.0	380 ±30	69 ±10
17	9.14	5910	10.4 ±0.7	4250 ±200	2750	7.8 ±0.4	12 ±7	0
18	13.9	8820	8.3 ±0.5	3830 ±200	3760	12.1 ±0.7	77 ±8	0
19	19.9	6630	6.3 ±0.7	3850 ±200	4280	16.0 ±1.1	132 ±13	9 ±9
20	30.9	1670	12.7 ±0.8	3460 ±180	1515	11.0 ±0.6	170 ±20	10 ±3
Average		6660 ±1540	8.9 ±2.2	3990 ±220	2960 ±820	11.1 ±3.6	146 ±119	16 ±16
Over-all average		6550 ±1690	9.8 ±2.6	3980 ±380	2910 ±980	10.3 ±4.3	260 ±220	34 ±34
Whole-rock matrix	320	7470 ±150	10.4 ±0.5	3450 ±70	2790 ±110	16.7 ±0.5	490 ±10	62 ±9

[a]See footnote (a) of Table 13.
[b]Magnetic chondrule indicated with (m).

Table 19

ABUNDANCES OF Na, Mn, AND Cu IN INDIVIDUAL CHONDRULES AND OLIVINE CRYSTALS OF SANTA CRUZ (TYPE II CARBONACEOUS CHONDRITE) AS DETERMINED BY INAA[a]

Chondrule	Mass (mg)	Na (ppm)	Mn (ppm)	Cu (ppm)
1	0. 102	790 ±40	1670 ±30	0 ±20
2	0. 309	870 ±30	1170 ±20	36 ± 7 (D)
3	0. 310	910 ±30	1190 ±20	110 ±30
4	0. 333	470 ±20	790 ±20	23 ±20
5	0. 501	960 ±30	1050 ±20	75 ±15 (D)
6	0. 52	1210 ±40	1300 ±20	79 ±1 (D)
7	0. 56	950 ±30	1050 ±20	77 ±15 (D)
8	0. 58	750 ±20	940 ±20	43 ±5
Average		860 ±150	1150 ±190	55 ±29
9	2. 33	1470 ±30	1320 ±20	31 ±20 (D)
10	3. 52	1340 ±20	1130 ±20	42 ±2 (D)
11	3. 54	1360 ±30	1250 ±70	43 ±12 (D)
Average		1390 ±50	1230 ±70	39 ±5
Over-all average		1010 ±250	1170 ±160	51 ±25
Whole chondrite	292	4060 ±80	1620 ±30	
Olivines	0. 040	180 ±80	270 ±10	70 ±140
	0. 080	80 ±30	2280 ±40	73 ±18 (D)
	0. 318	370 ±20	1230 ±20	197 ±23 (D)
Average		210 ±110	1260 ±680	113 ±56

[a]See footnote (a) of Table 13.

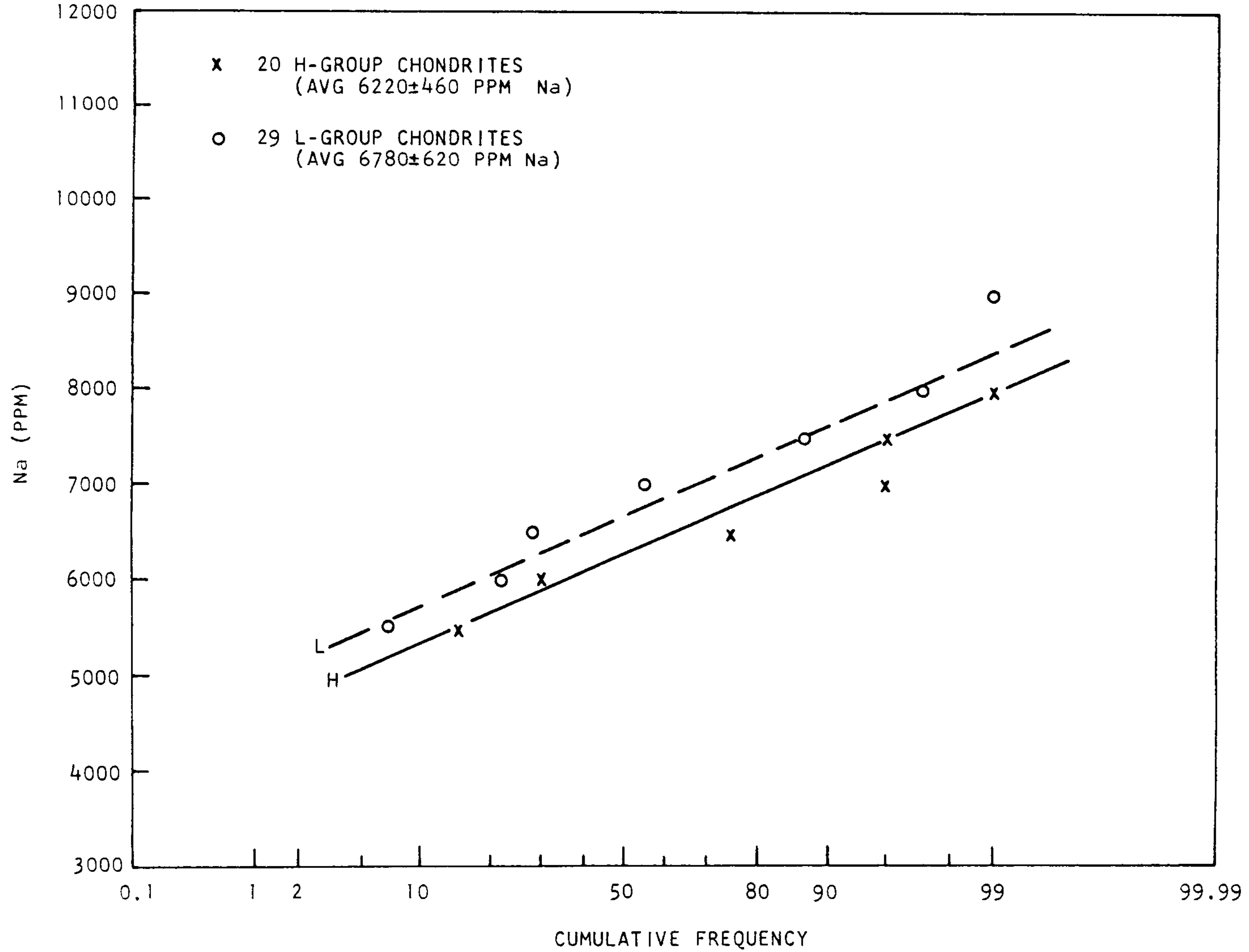

Fig. 1--Cumulative frequency distribution of Na in 20 H-group chondrites and 29 L-group chondrites

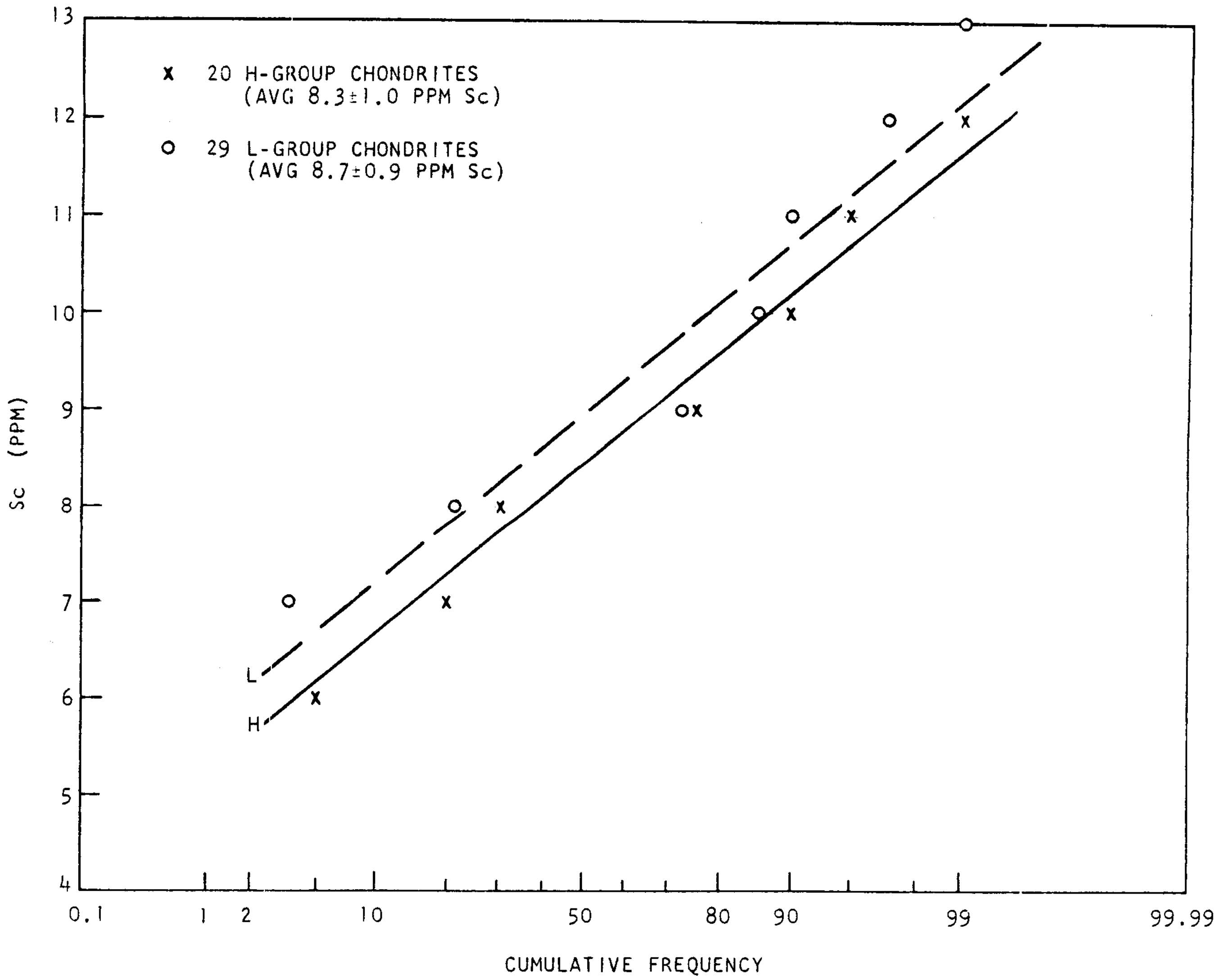

Fig. 2--Cumulative frequency distribution of Sc in 20 H-group chondrites and 29 L-group chondrites

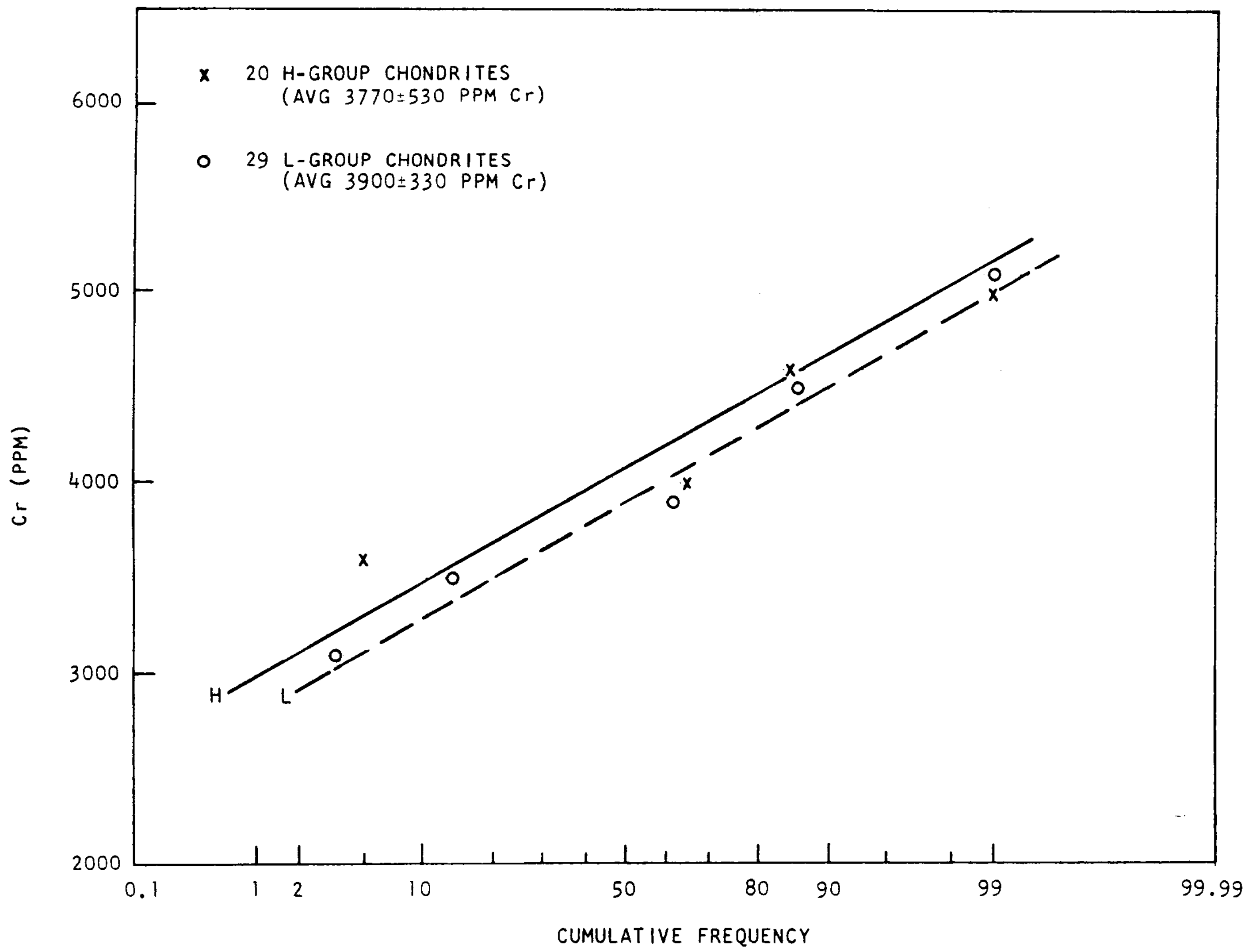

Fig. 3--Cumulative frequency distribution of Cr in 20 H-group chondrites and 29 L-group chondrites

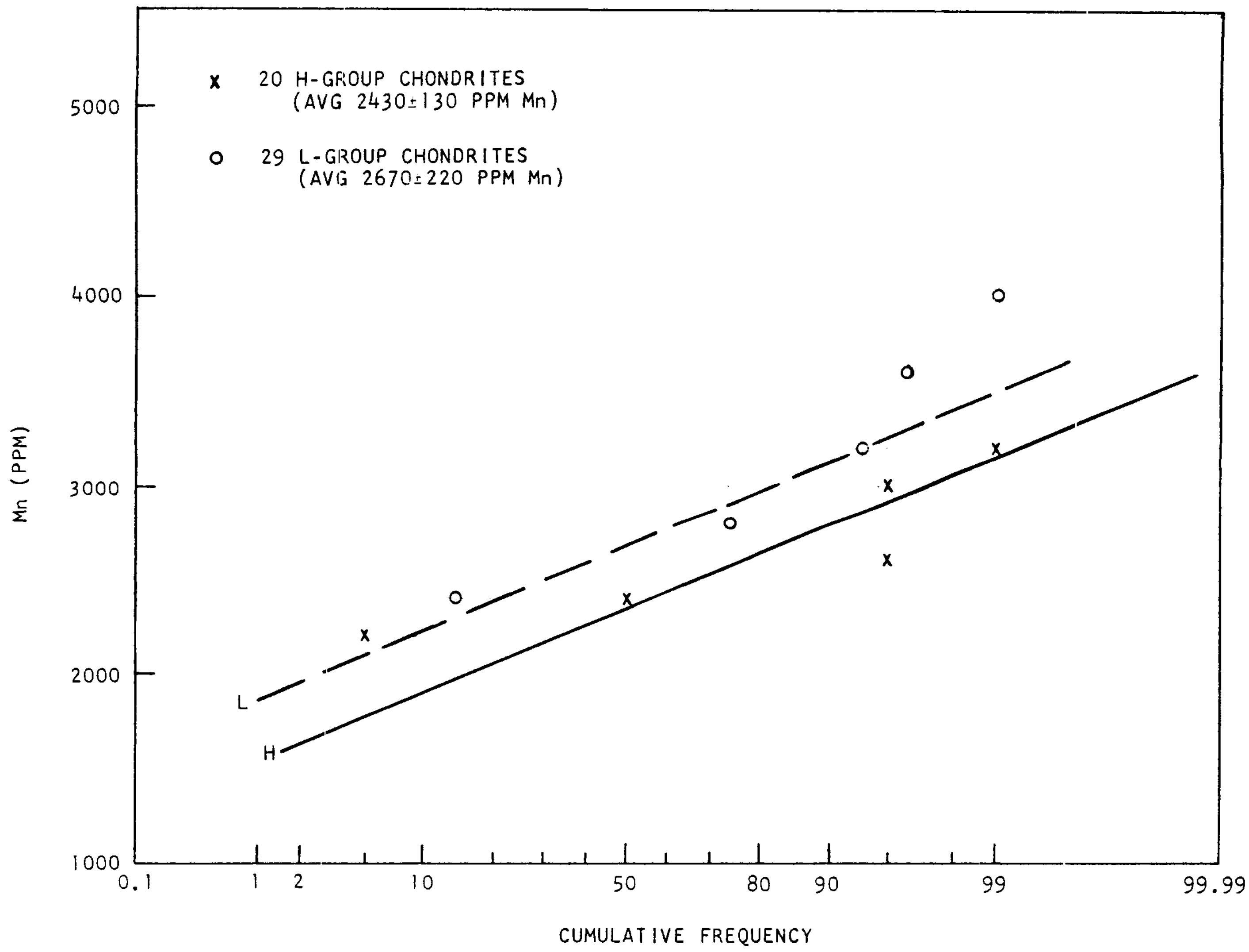

Fig. 4--Cumulative frequency distribution of Mn in 20 H-group chondrites and 29 L-group chondrites

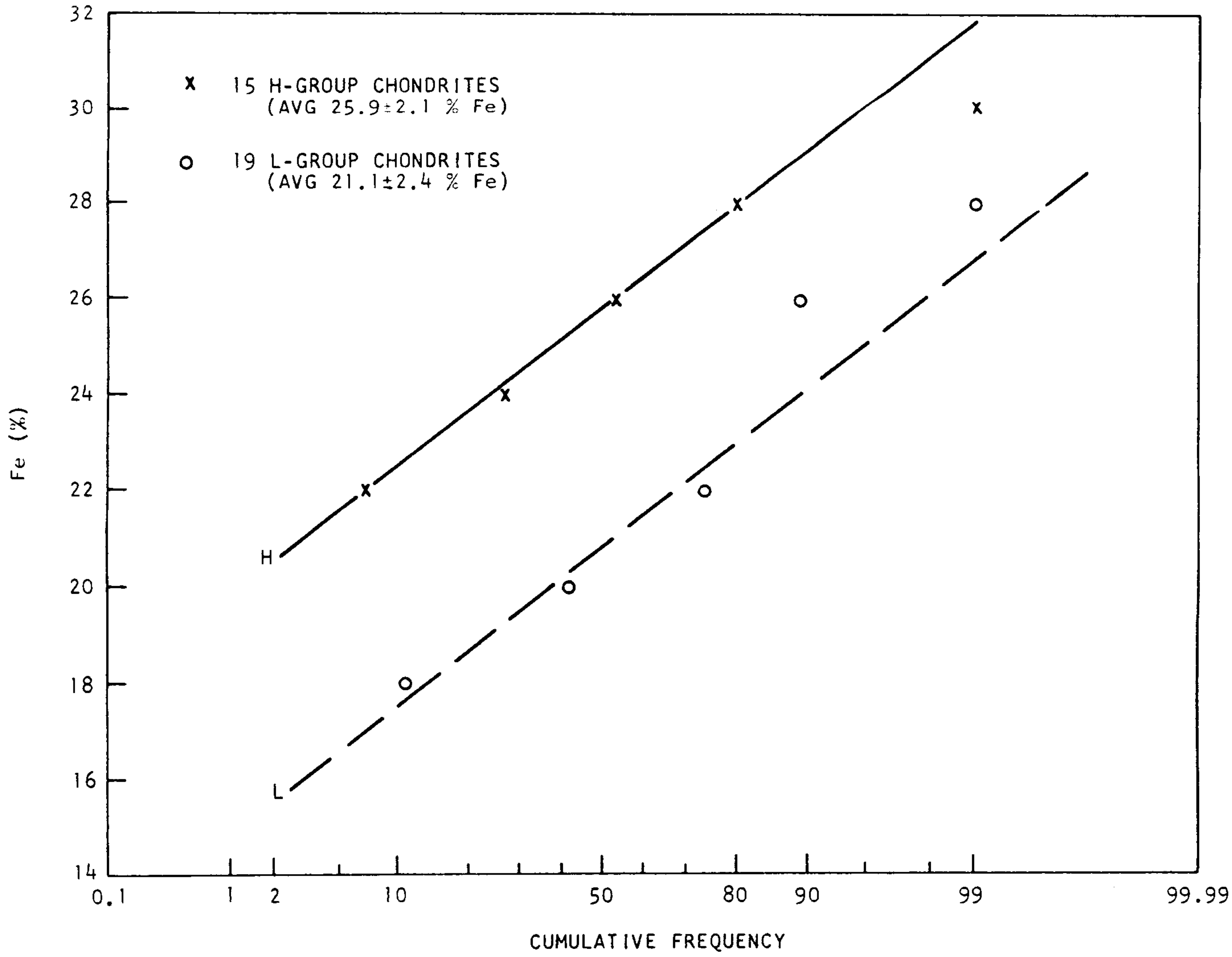

Fig. 5--Cumulative frequency distribution of Fe in 15 H-group chondrites and 19 L-group chondrites

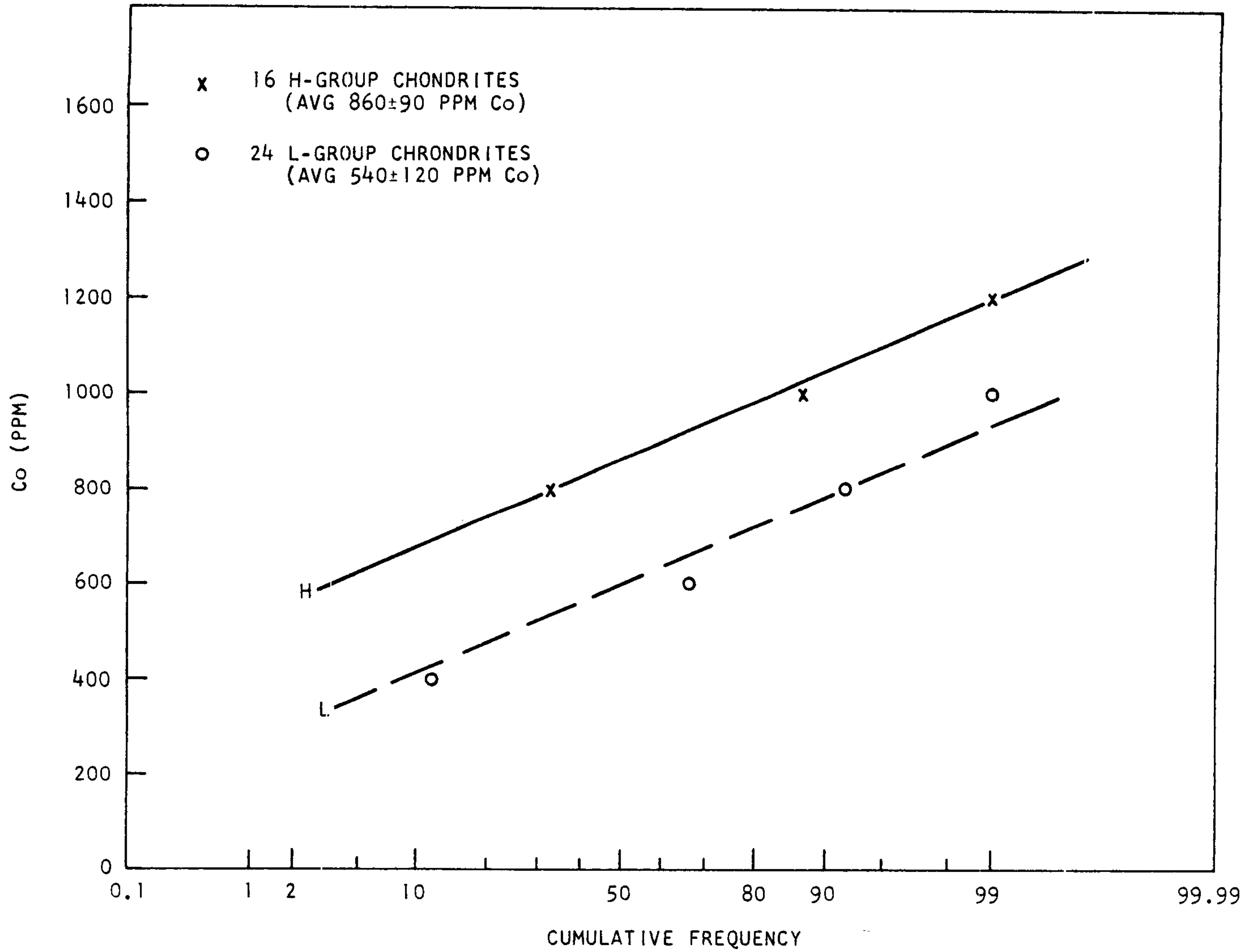

Fig. 6--Cumulative frequency distribution of Co in 16 H-group chondrites and 24 L-group chondrites

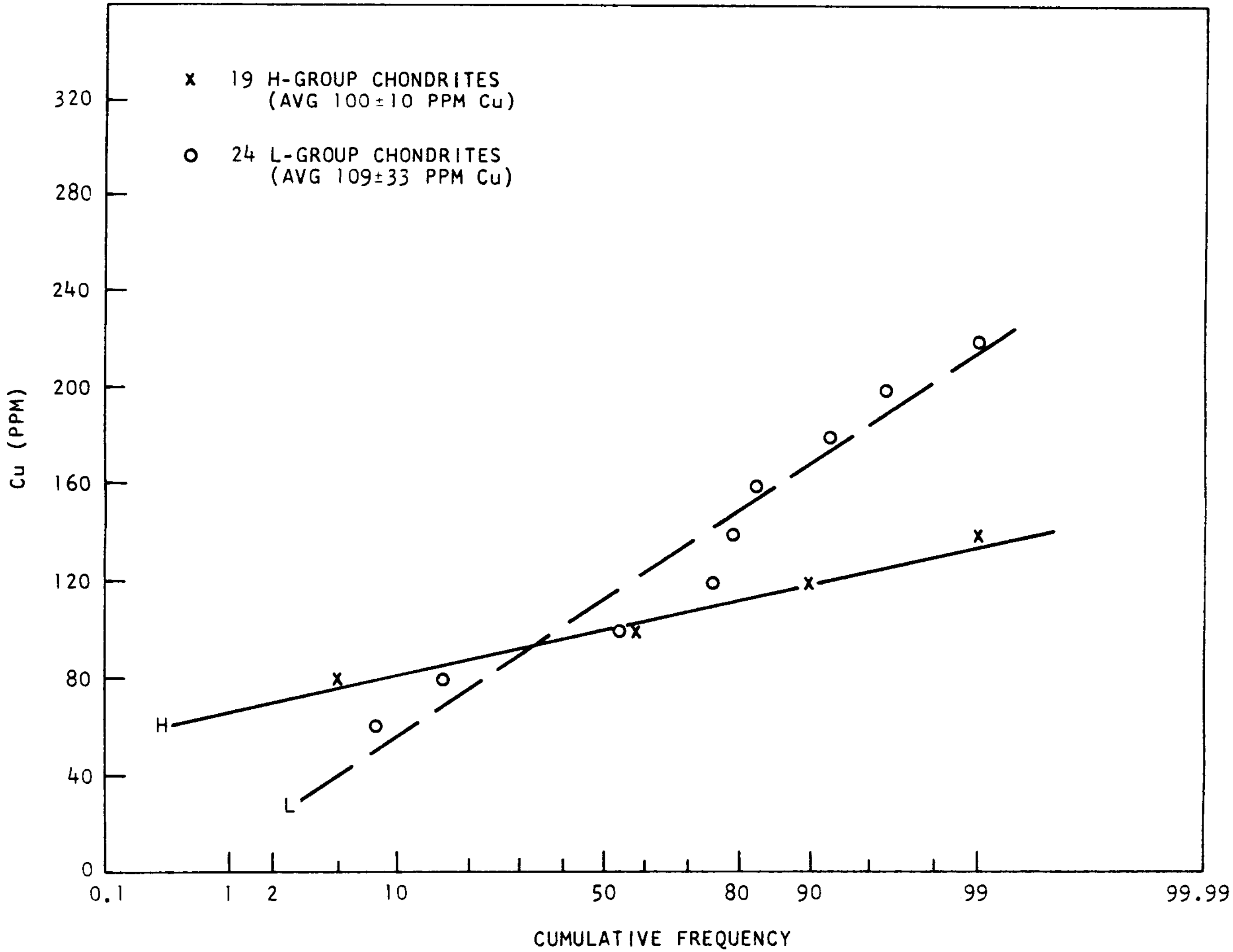

Fig. 7--Cumulative frequency distribution of Cu in 19 H-group chondrites and 24 L-group chondrites

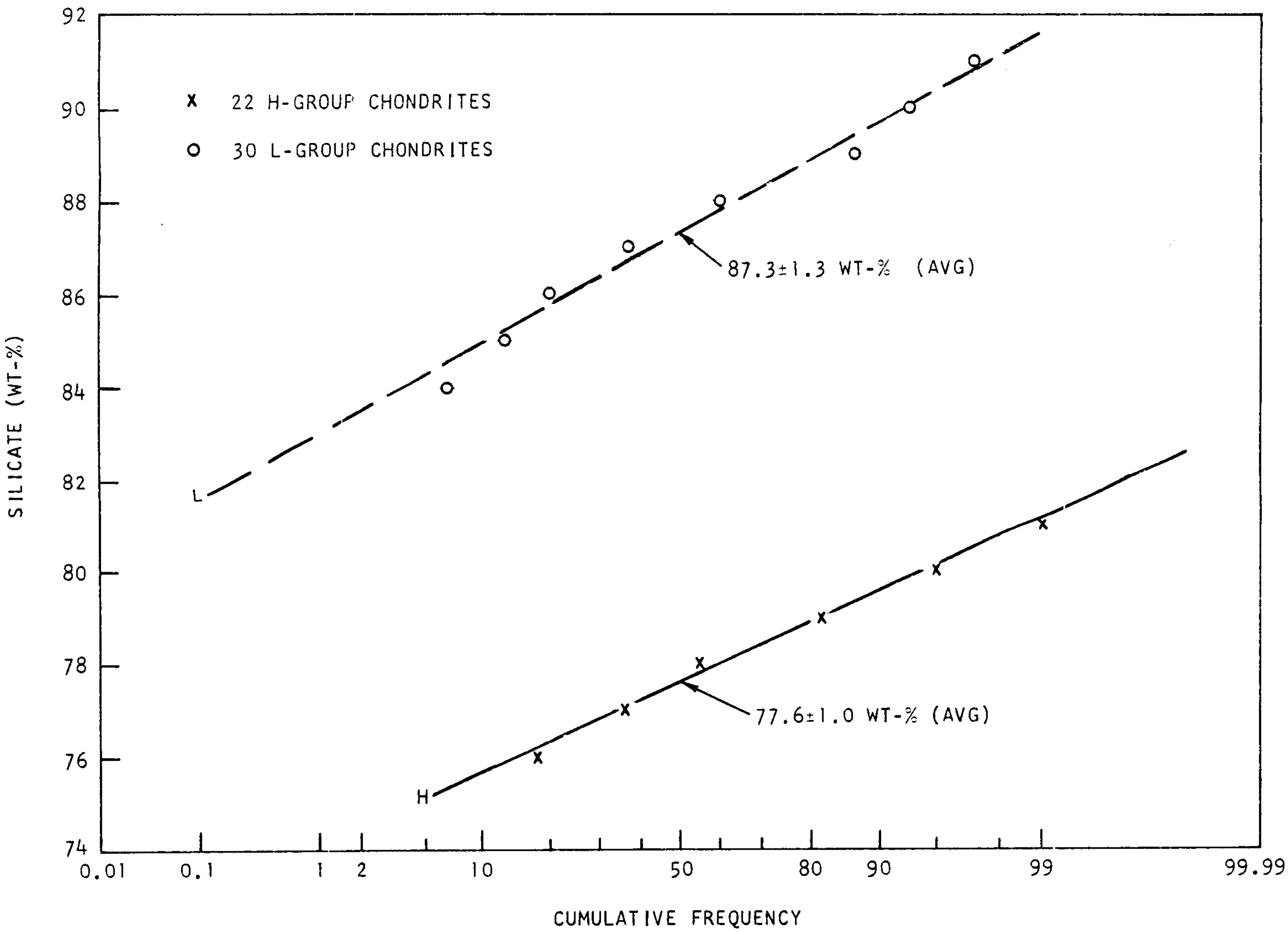

Fig. 8--Cumulative frequency distribution of total silicates in 52 ordinary chondrites (falls); data are taken from Keil, Ref. 6

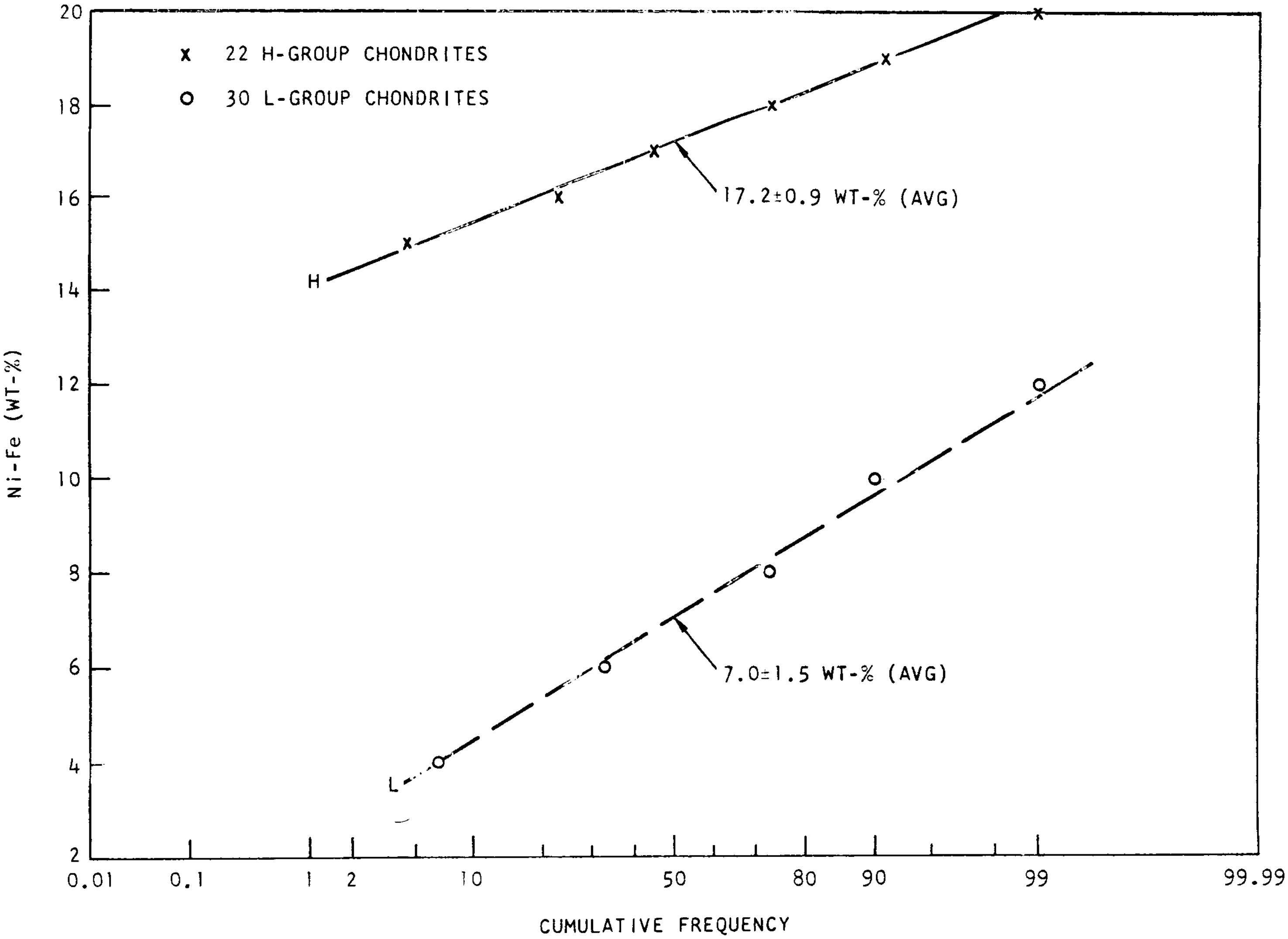

Fig. 9--Cumulative frequency distribution of metallic Fe-Ni in 52 ordinary chondrites (falls); data are taken from Keil, Ref. 6

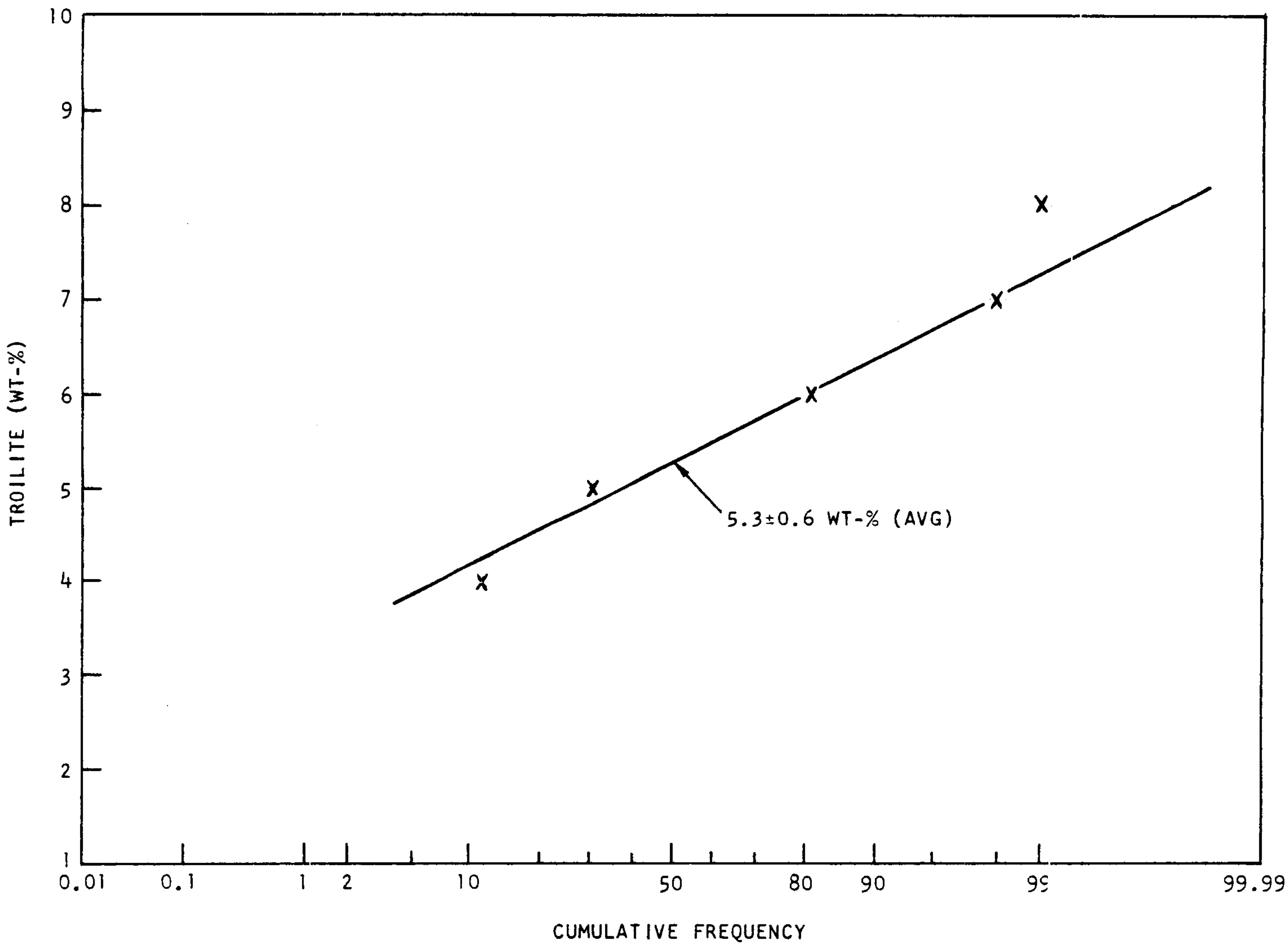

Fig. 10--Cumulative frequency distribution of troilite in 52 ordinary chondrites (falls); data are taken from Keil, Ref. 6

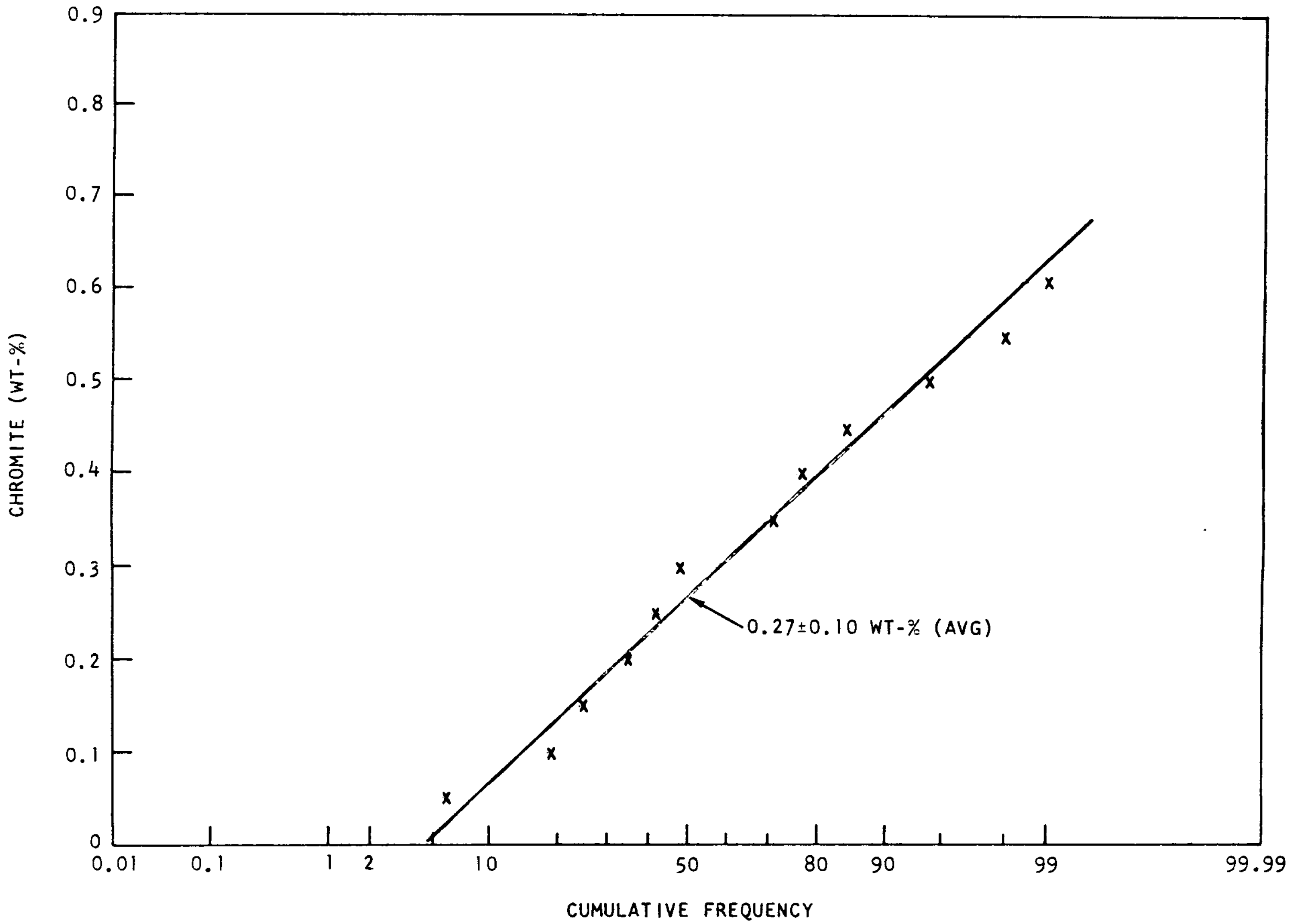

Fig. 11--Cumulative frequency distribution of chromite in 48 ordinary chondrites (falls); data are taken from Keil, Ref. 6

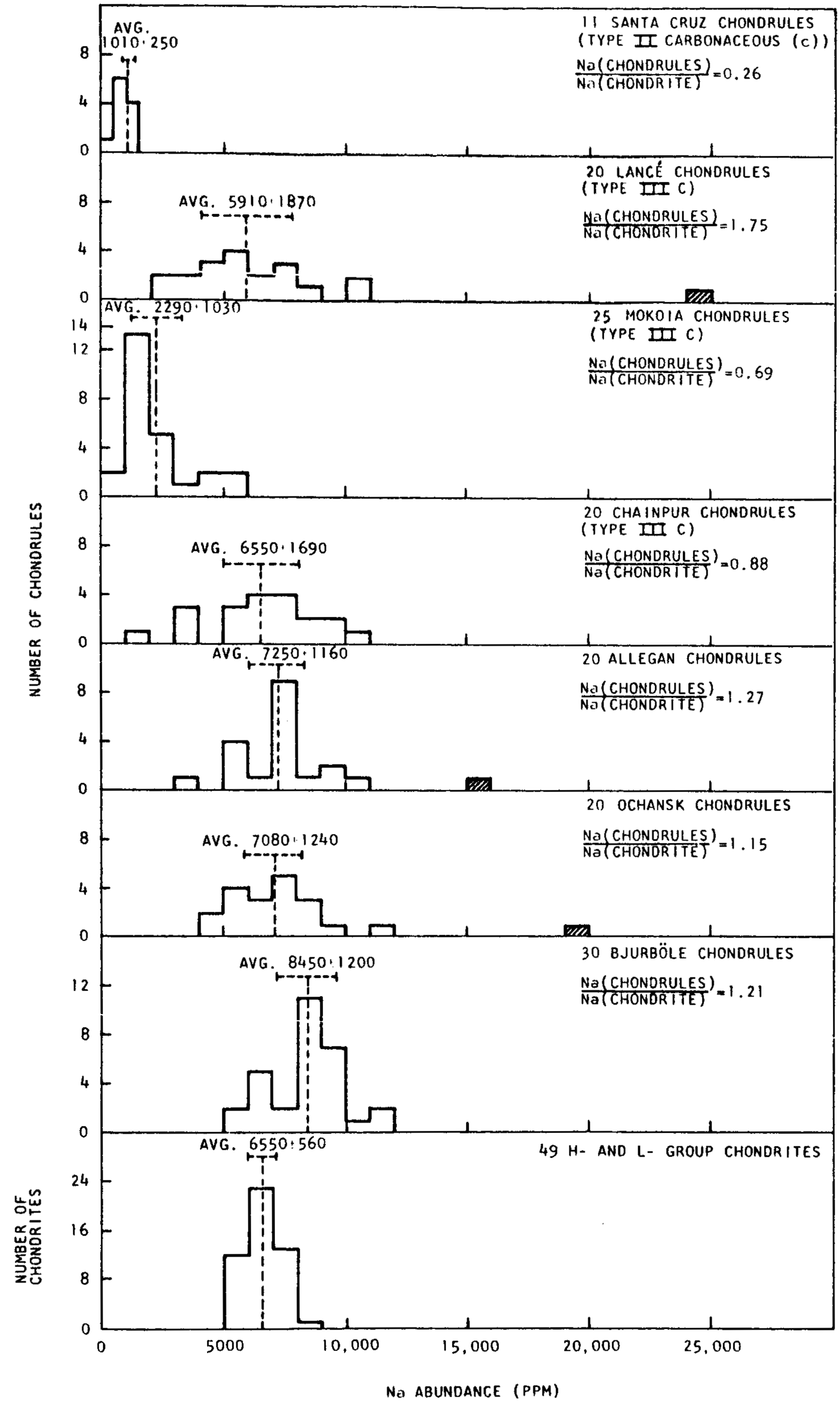

Fig. 12--Histogram of Na abundance in chondrules separated from seven chondrites

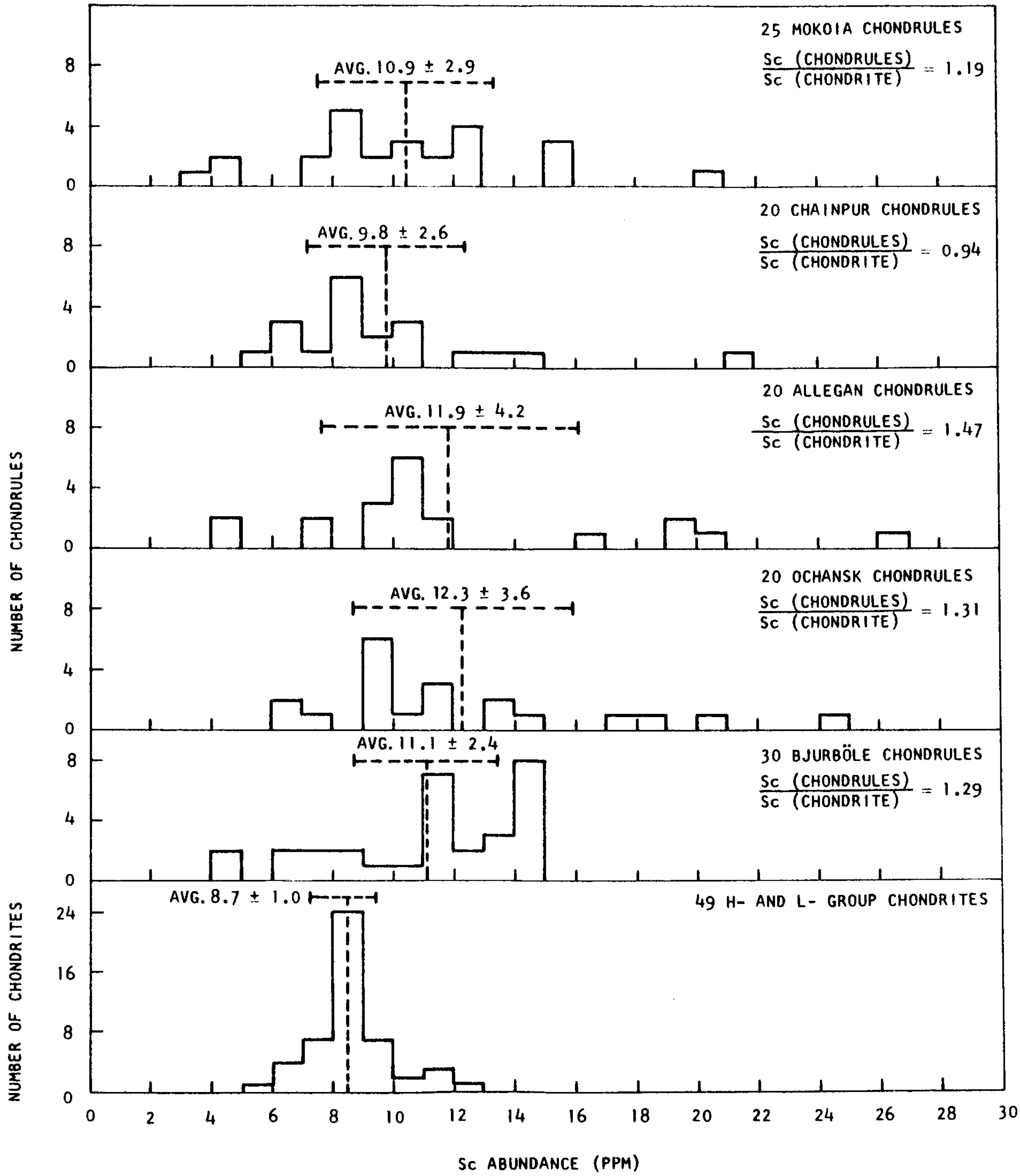

Fig. 13--Histogram of Sc abundance in chondrules separated from five chondrites

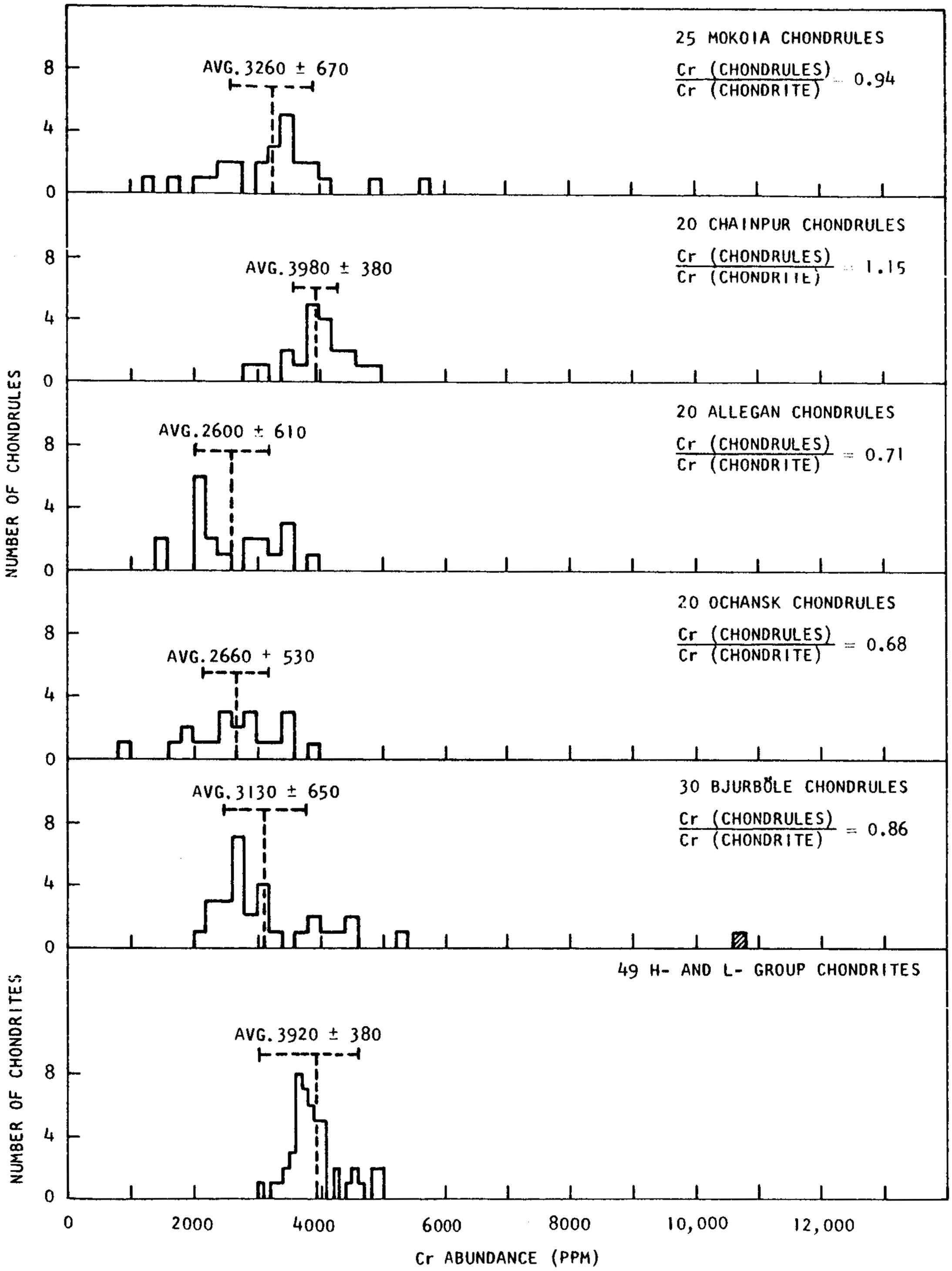

Fig. 14--Histogram of Cr abundance in chondrules separated from five chondrites

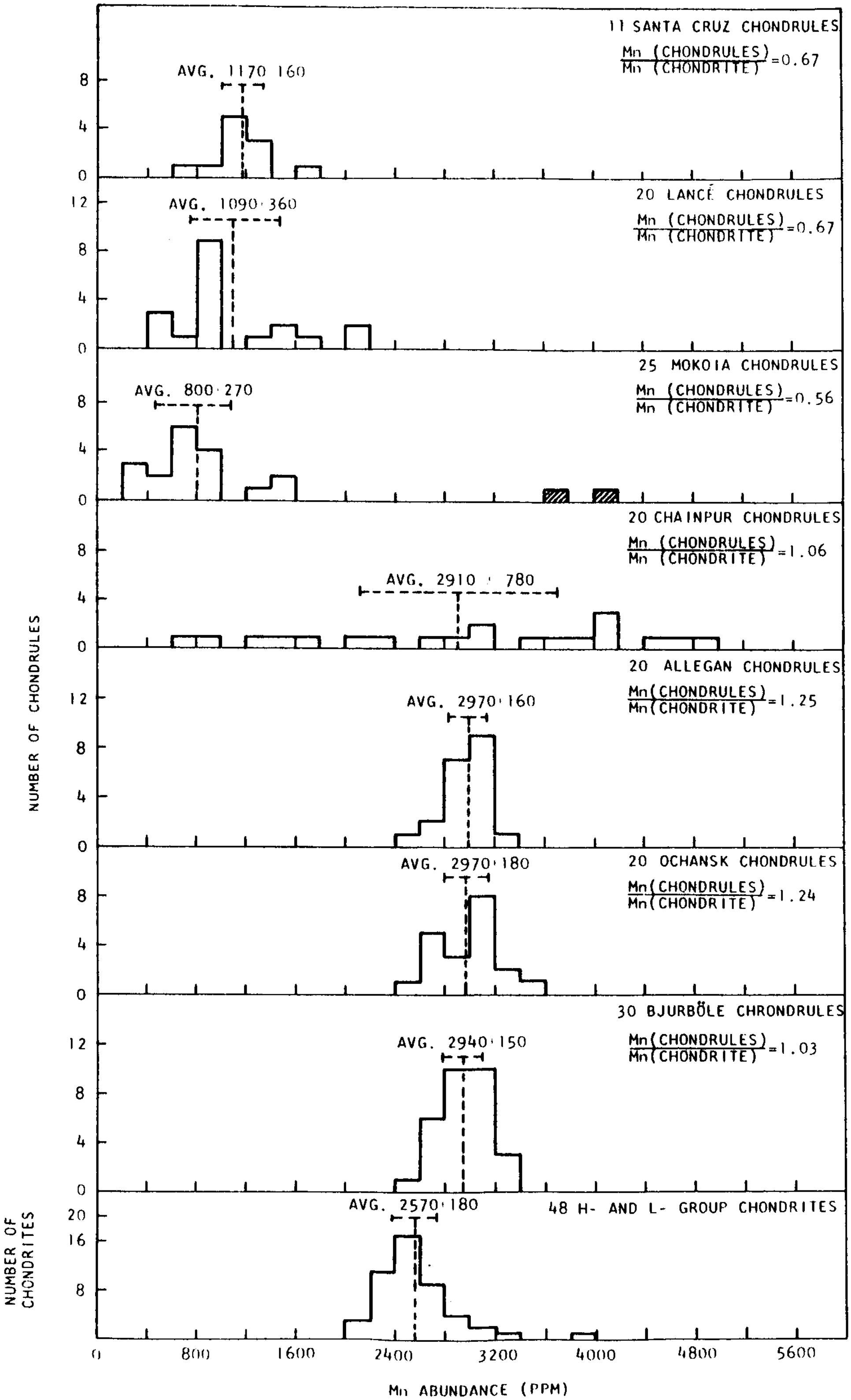

Fig. 15--Histogram of Mn abundance in chondrules separated from seven chondrites

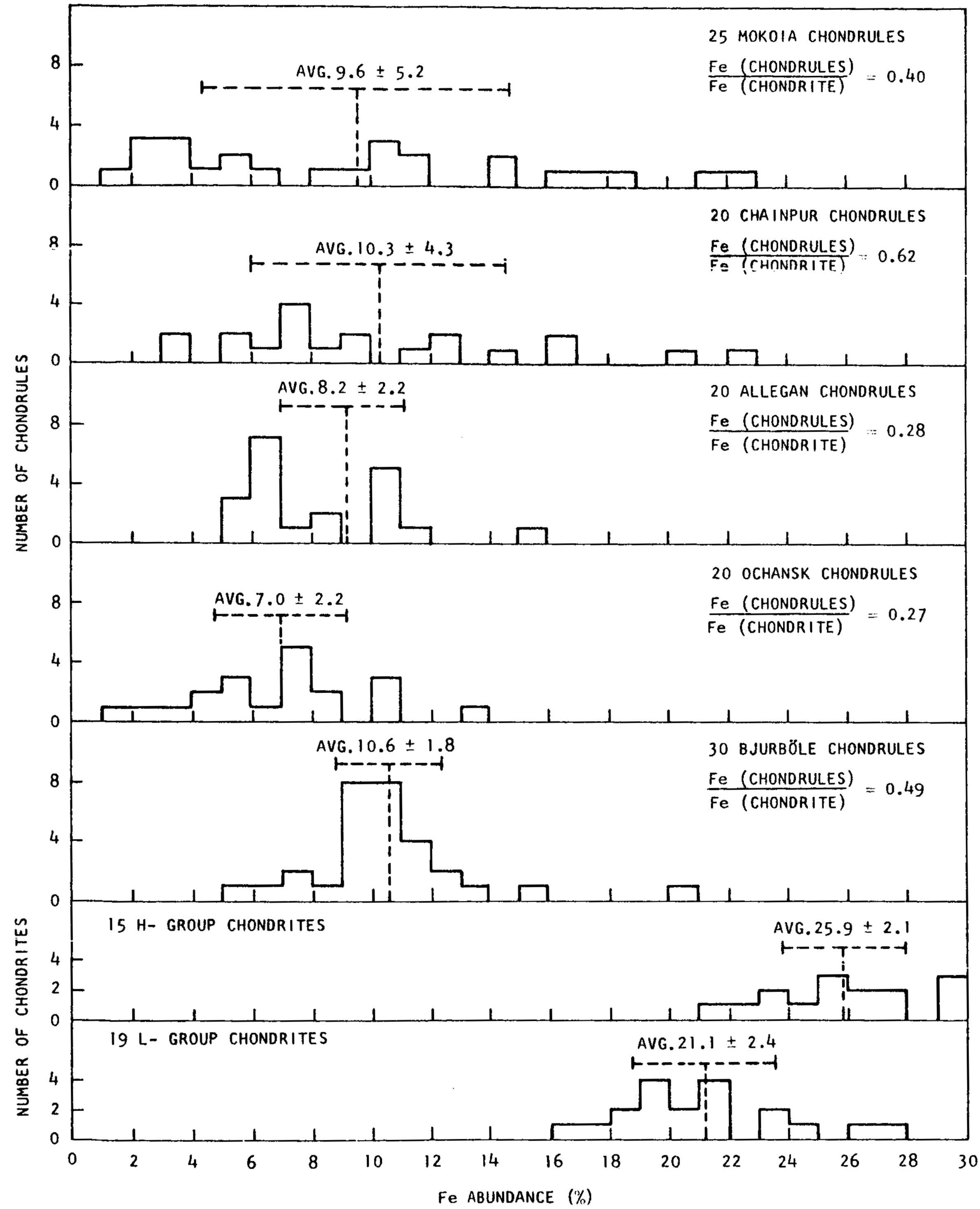

Fig. 16--Histogram of Fe abundance in chondrules separated from five chondrites

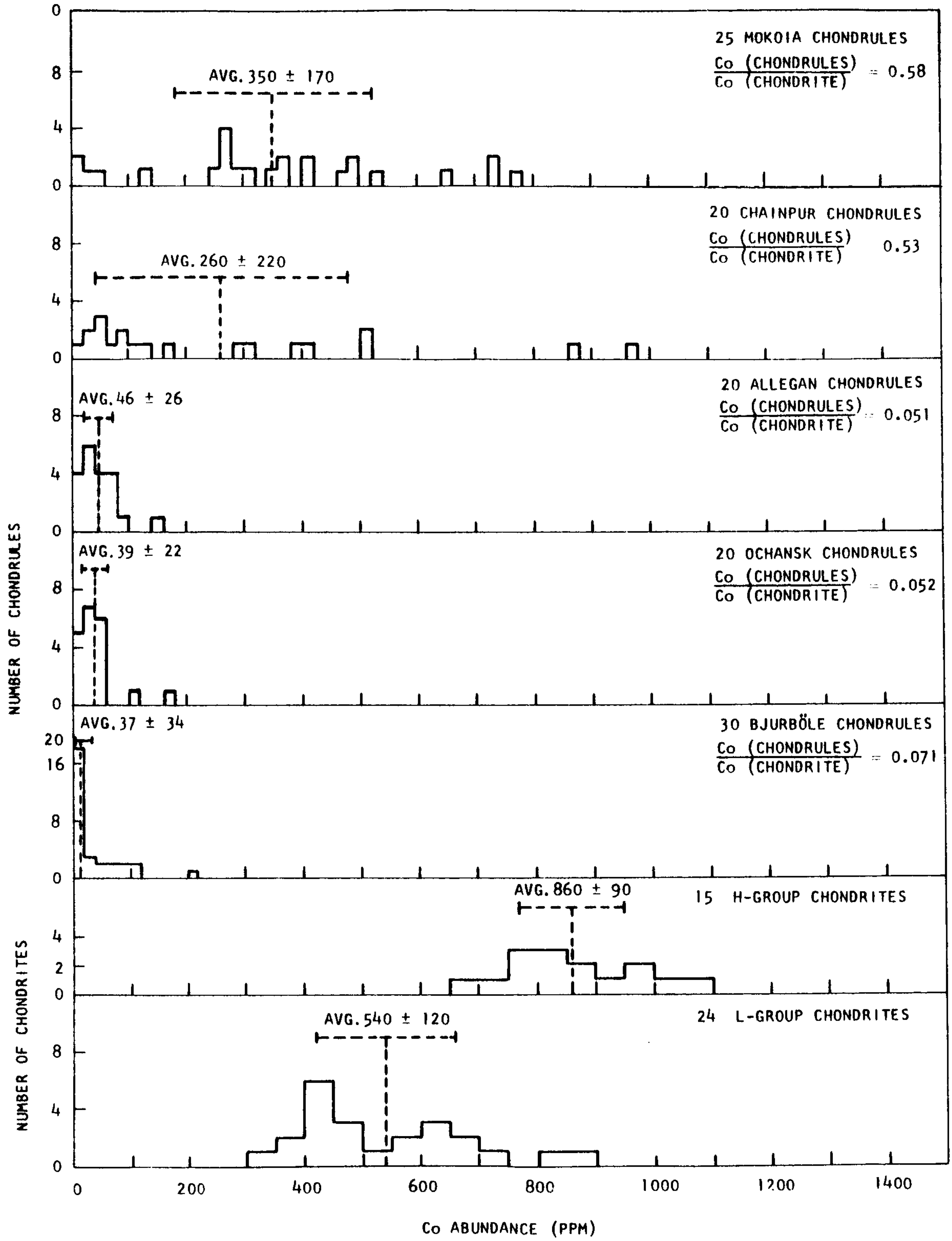

Fig. 17--Histogram of Co abundance in chondrules separated from five chondrites

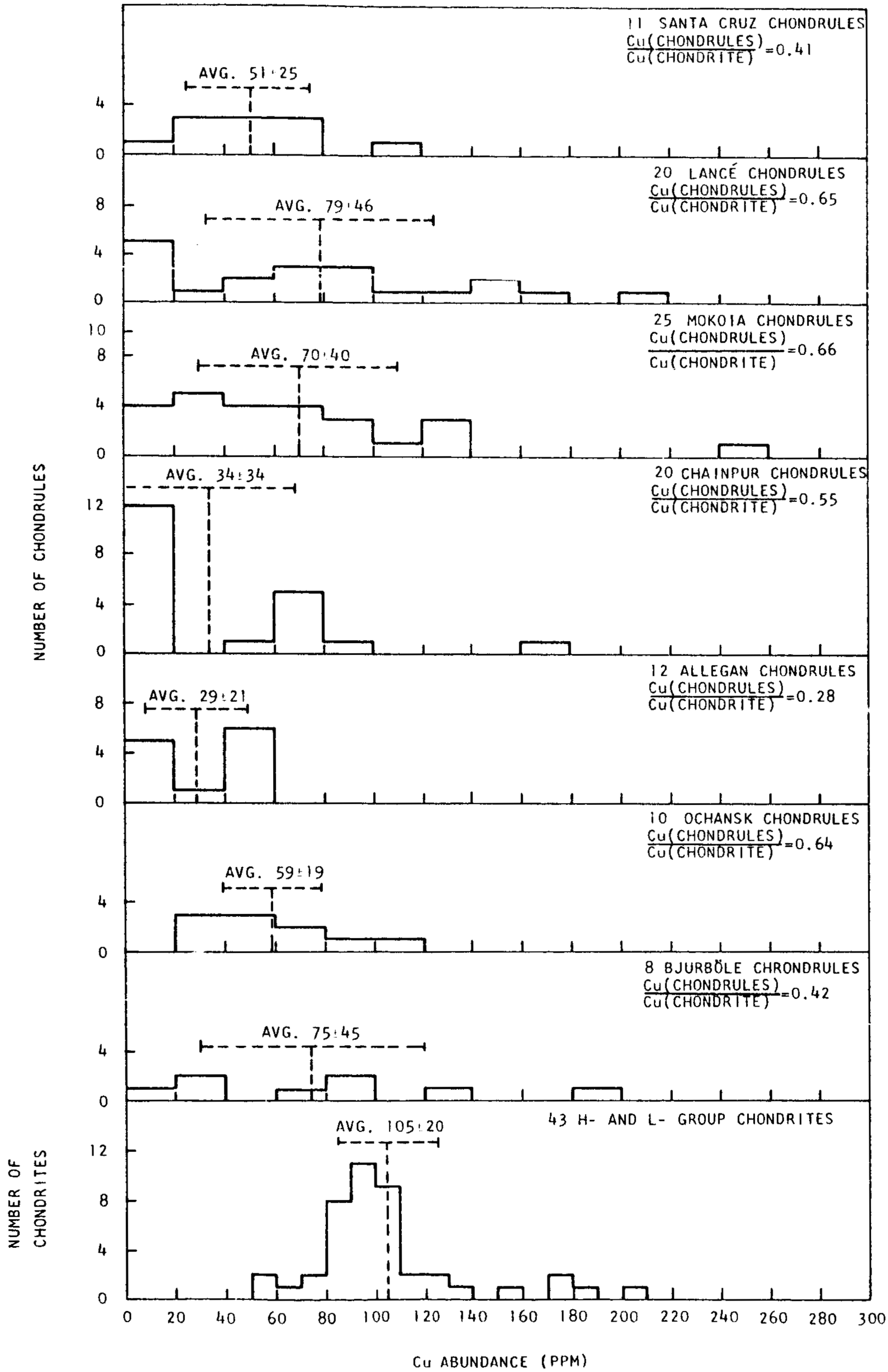

Fig. 18--Histogram of Cu abundance in chondrules separated from seven chondrites

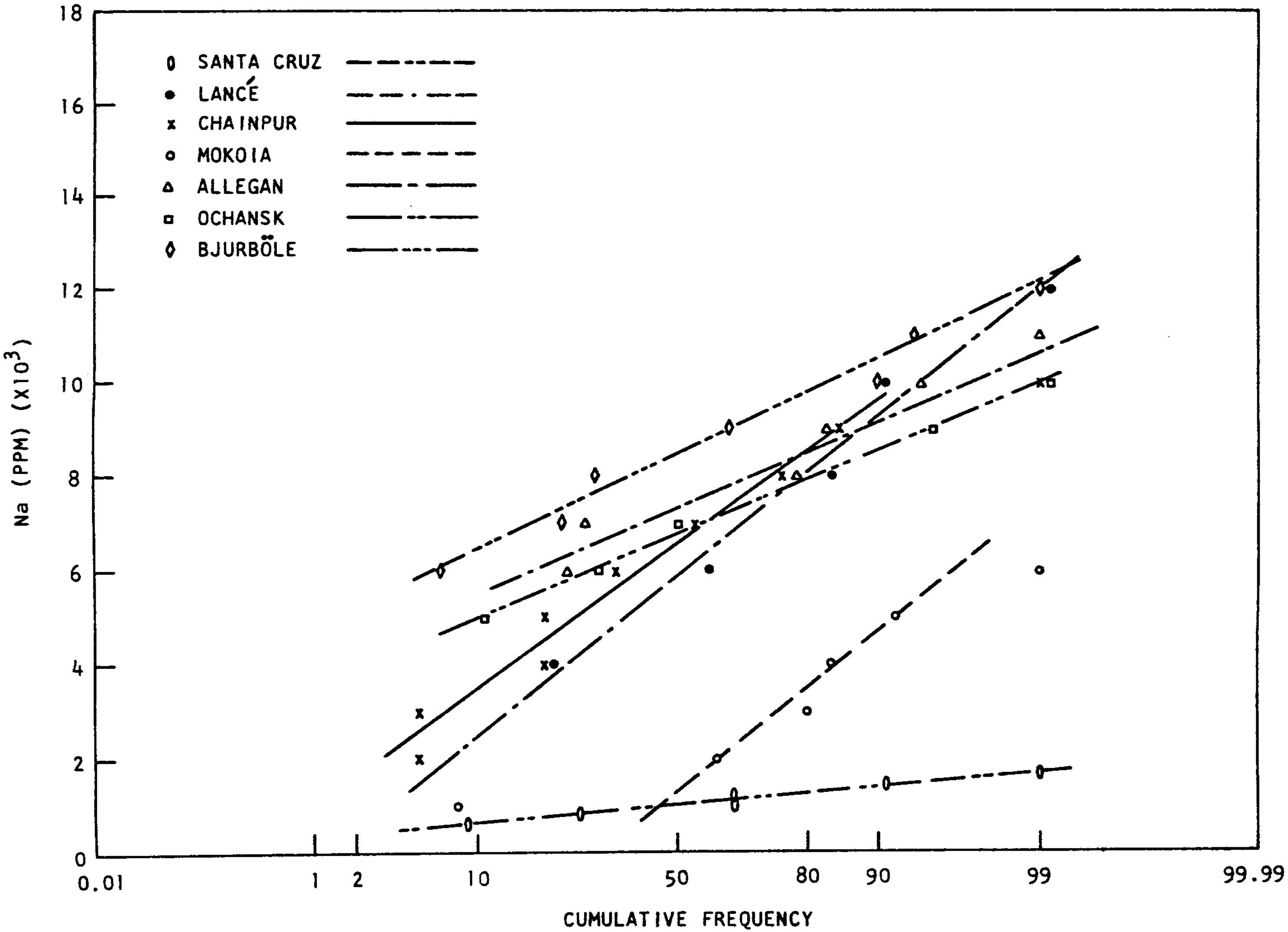

Fig. 19--Cumulative frequency distributions of Na in chondrules separated from seven chondrites

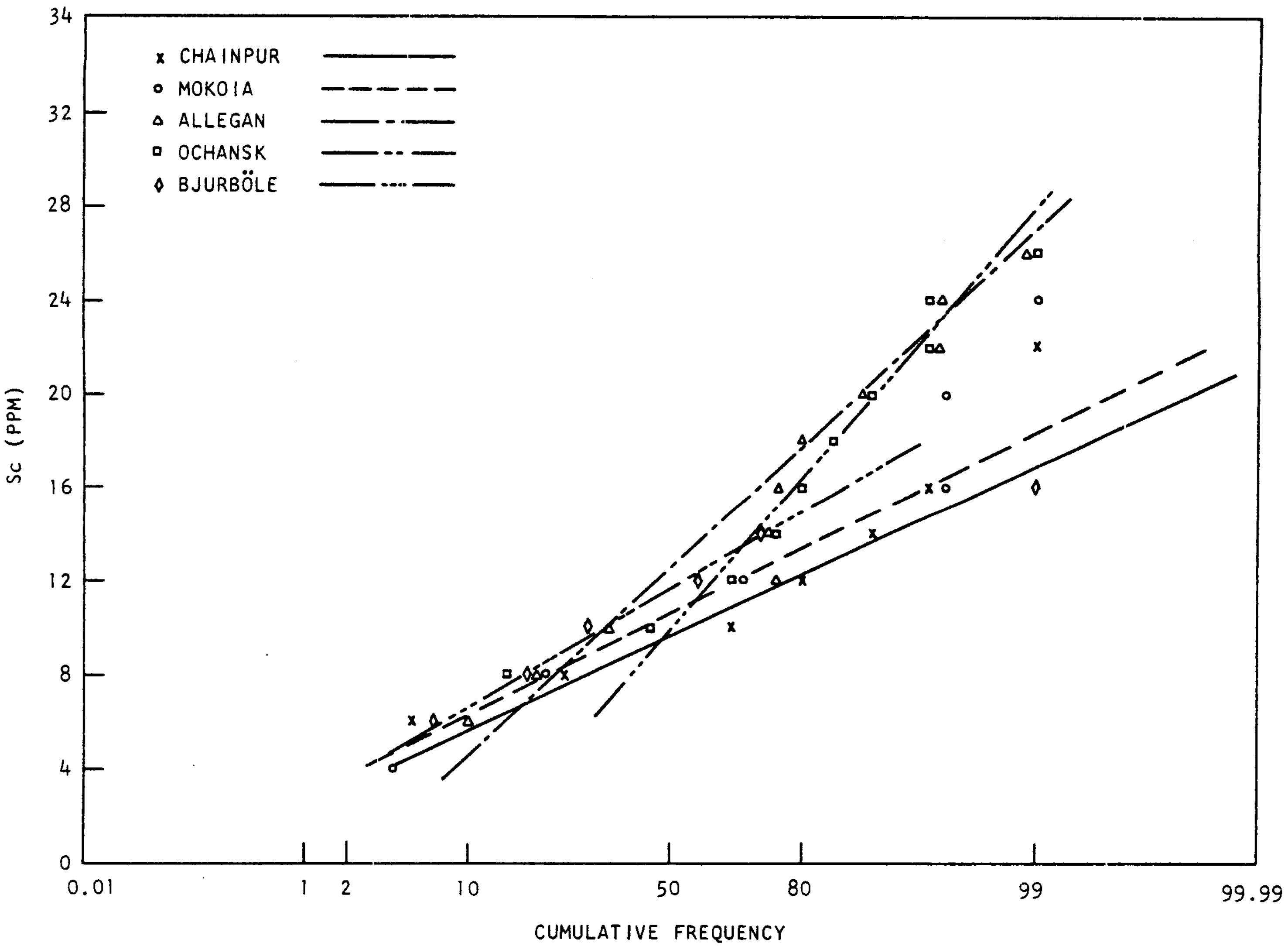

Fig. 20--Cumulative frequency distributions of Sc in chondrules separated from five chondrites

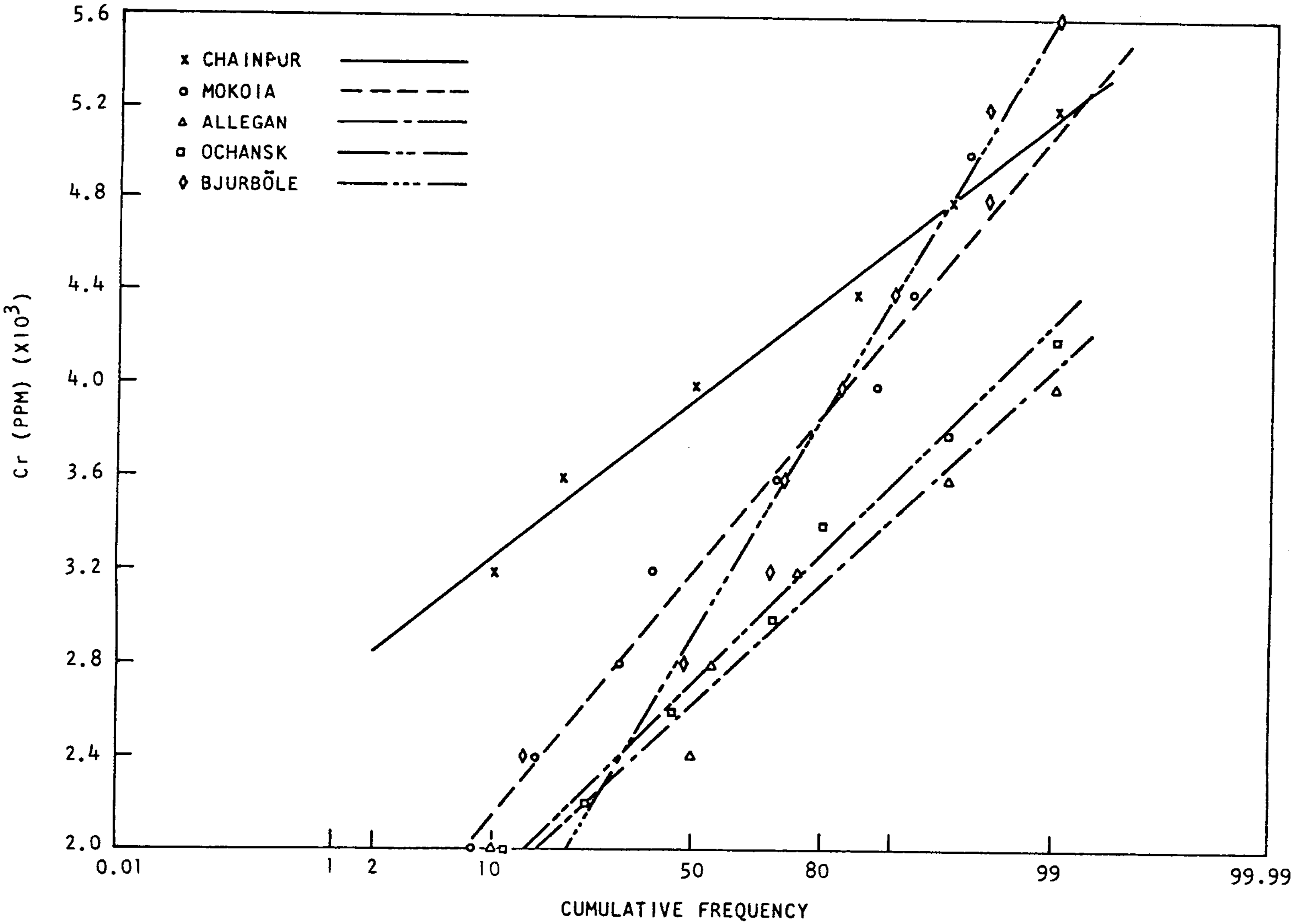

Fig. 21--Cumulative frequency distributions of Cr in chondrules separated from five chondrites

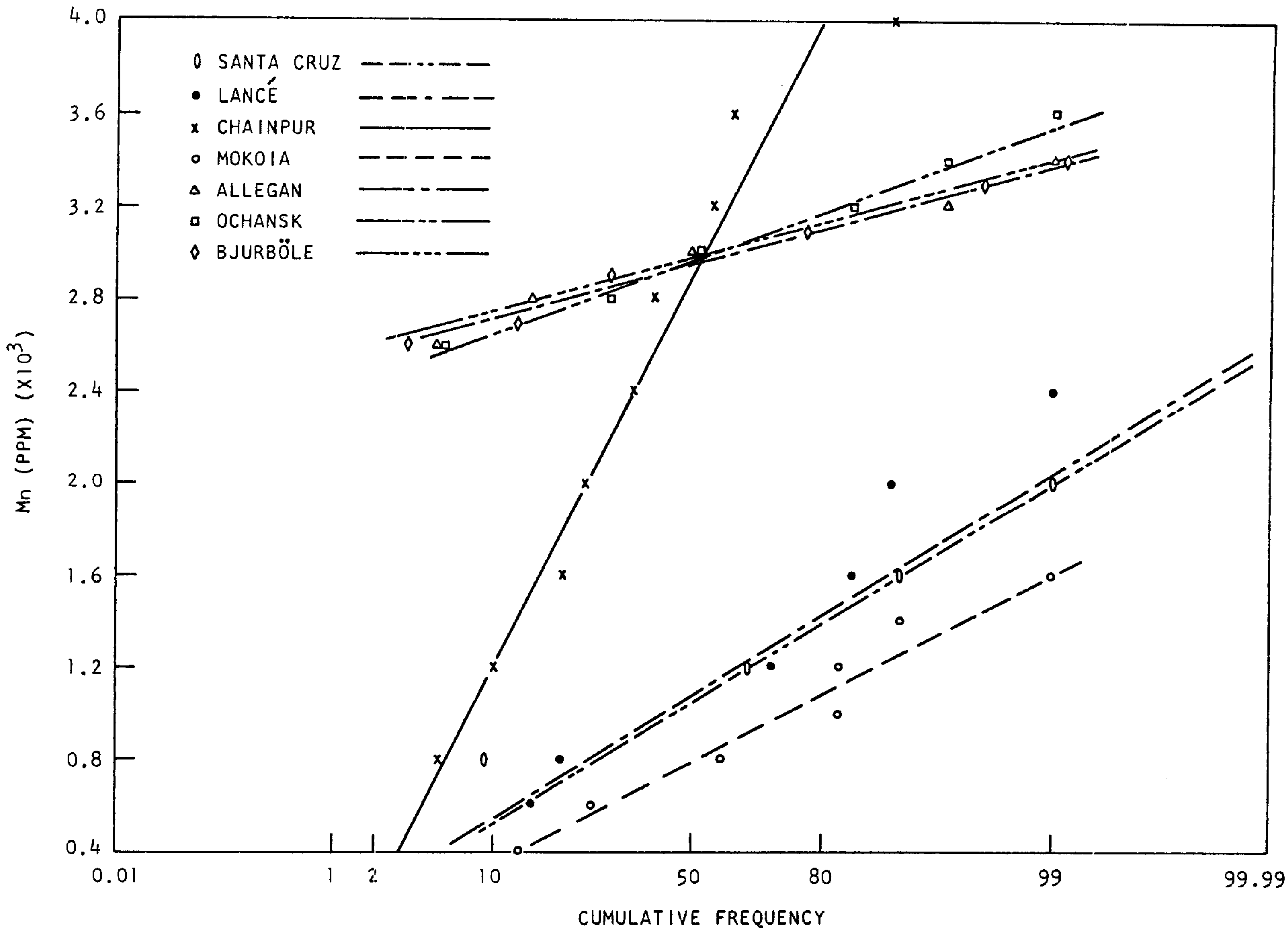

Fig. 22--Cumulative frequency distributions of Mn in chondrules separated from seven chondrites

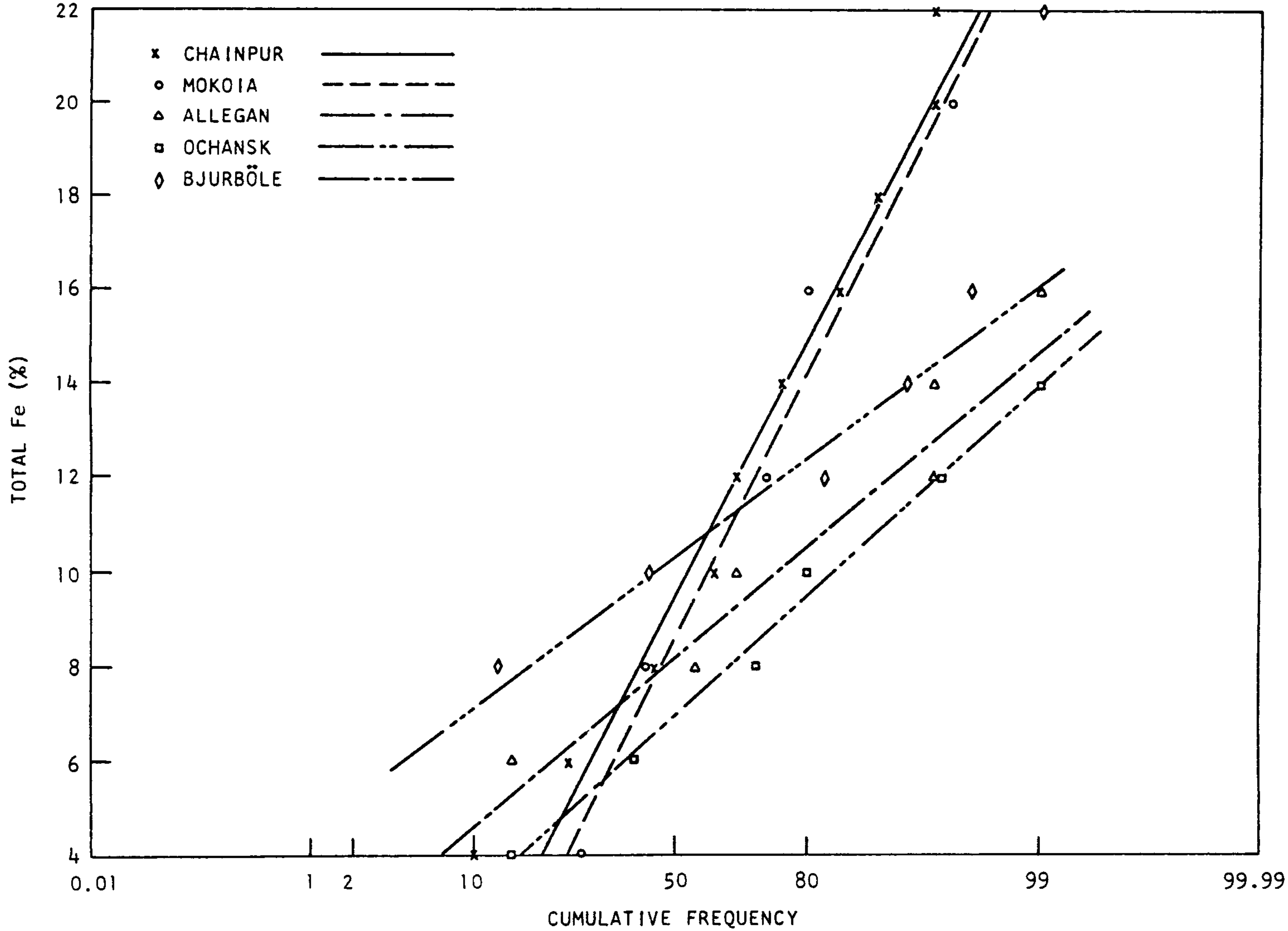

Fig. 23--Cumulative frequency distributions of Fe in chondrules separated from five chondrites

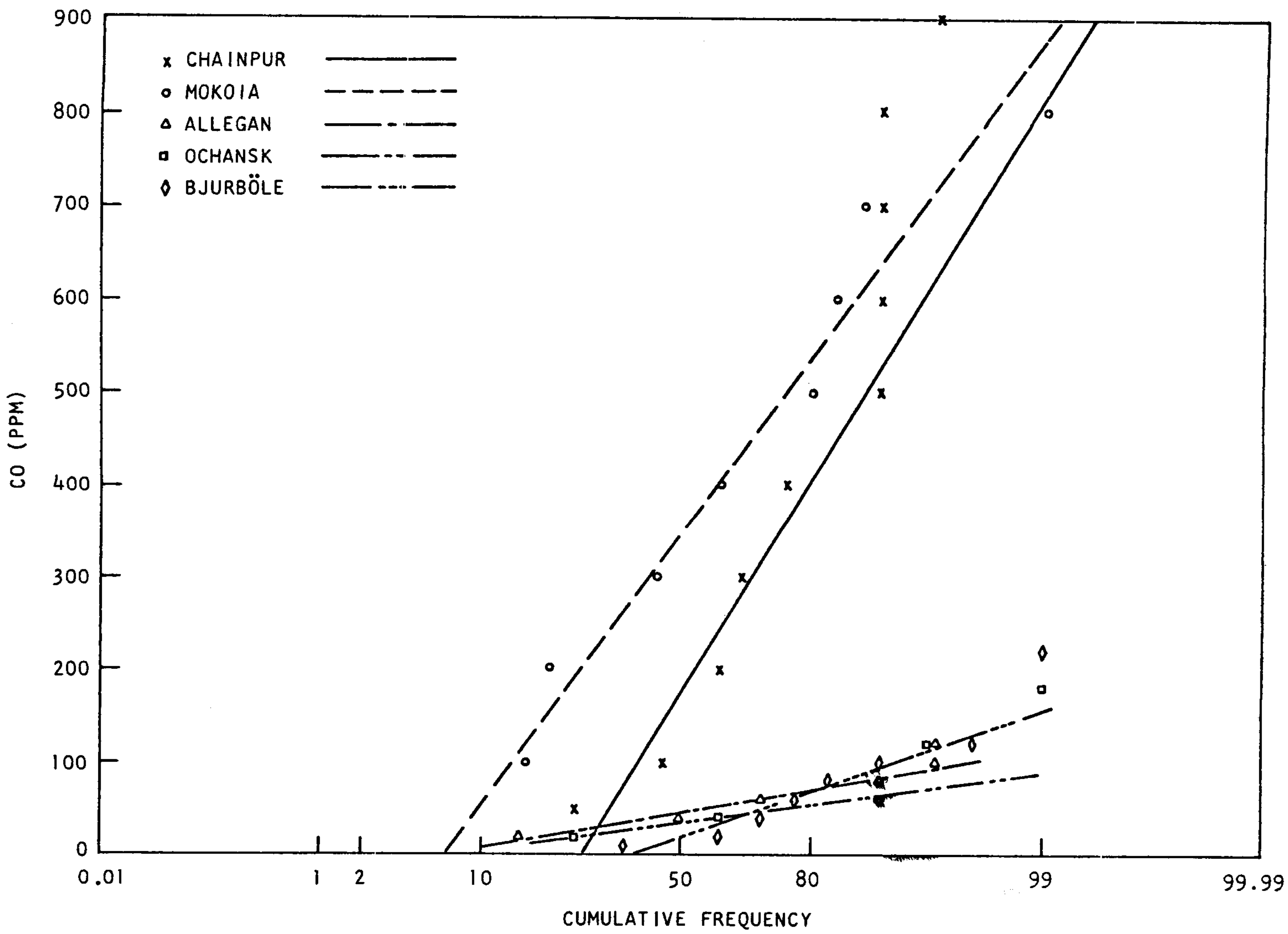

Fig. 24--Cumulative frequency distributions of Co in chondrules separated from five chondrites

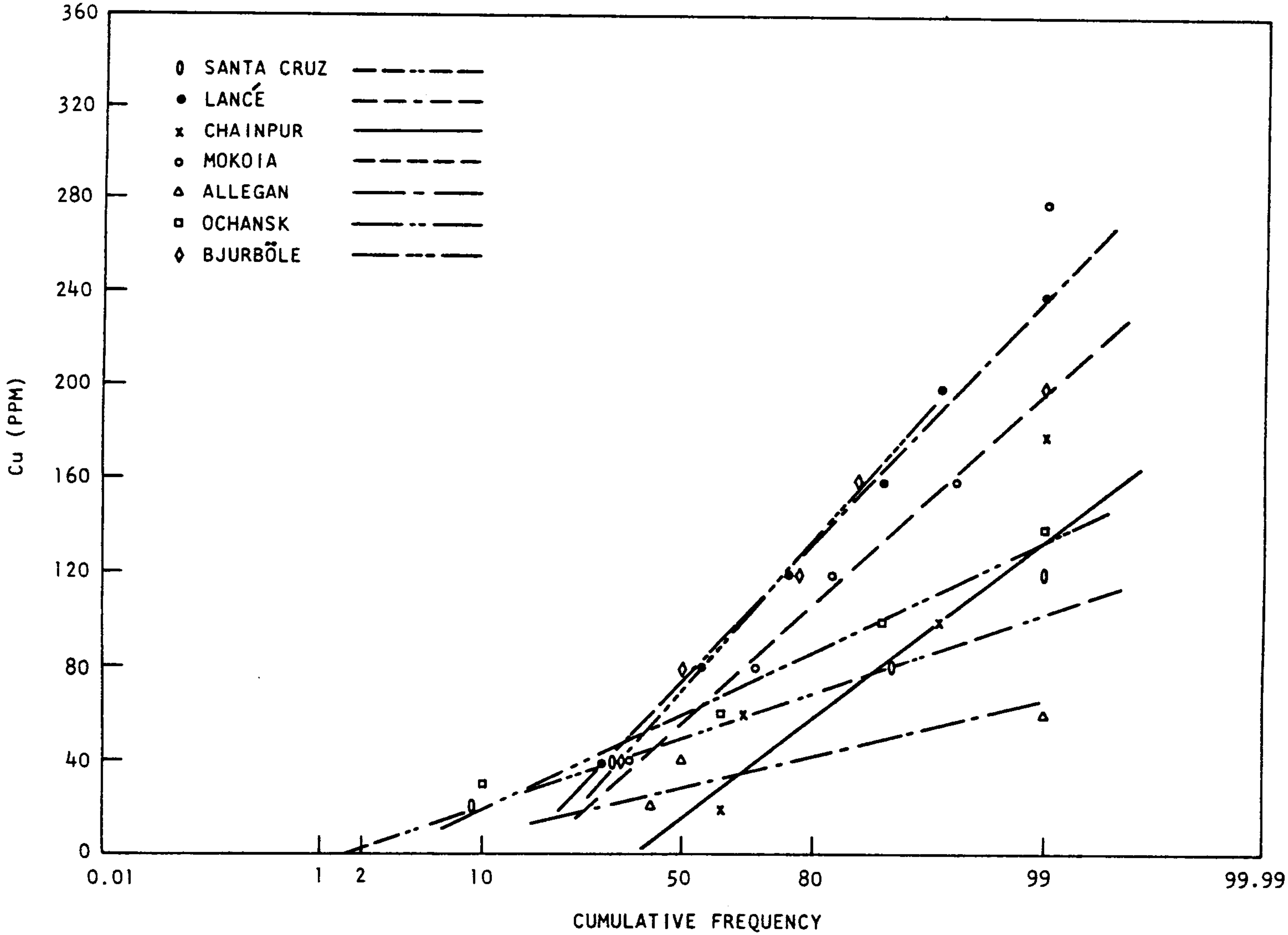

Fig. 25--Cumulative frequency distributions of Cu in chondrules separated from seven chondrites

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